U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF ENTOMOLOGY.

BULLETIN NO. 29.

REPORT

ON THE

BOLL WORM OF COTTON

(*Heliothis armiger* Hübn.).

MADE UNDER THE DIRECTION OF THE ENTOMOLOGIST

BY

F. W. MALLY.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., October 31, 1892.

SIR: I have the honor to transmit herewith, for publication as Bulletin No. 29 of this Division, a report by Mr. F. W. Mally upon the Boll Worm of Cotton (*Heliothis armiger* Hübn.), the first part covering his observations upon the parasites and natural enemies of the Boll Worm while the second part is devoted to his bacteriological experiments with certain insect diseases affecting this larva.

Respectfully,

C. V. RILEY,
Entomologist.

HON. J. M. RUSK,
Secretary.

LETTER OF SUBMITTAL.

WASHINGTON, D. C., *May 1, 1892.*

SIR: I submit herewith a report upon the remedies for, and the parasites and natural enemies of, the Boll Worm (*Heliothis armiger* Hübn.) covering the results of investigations carried on under your direction.

Respectfully yours,

F. W. MALLY,
Assistant.

DR. C. V. RILEY,
Entomologist.

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ACKNOWLEDGMENTS.

My first acknowledgments are due to Dr. C. V. Riley and to Mr. L. O. Howard, who have furnished valuable aid in the determination of specimens; to Mr. E. A. Schwarz for identifying Coleoptera; to Mr. Theo. Pergande for naming ants, and also to Mr. Nathan Banks, who was assigned to me in my work at Shreveport, for determining spiders.

The planters at Shreveport deserve great praise for their uniform courtesy, hearty coöperation, and the many sacrifices made in devoting time and labor to the promotion of field experiments. Those who assigned portions of their plantations for the sole purpose of testing remedial measures, and who therefore deserve personal mention, are Messrs. J. H. Fullilove, Daniel Nicholson, S. J. Ziegler, and John Caldwell, all of Shreveport; Mr. M. A. Curtis, of Curtis, La., and Mr. John Glassell, jr., of Rush Point, La.

The wide geographical distribution of the Boll Worm, and the different natural conditions in the various regions where it occurs, made it quite impossible to cover the entire ground without the assistance and coöperation of intelligent persons throughout those regions. Accordingly arrangements were made with the several State weather services to have their observers give special attention to any facts of interest and value to the investigation. This was accomplished through the efforts of the directors of the several services. Mr. M. G. Wright, jr., of Shreveport, La.; Prof. R. B. Fulton, University, Miss.; Mr. F. H. Clark, Little Rock, Ark.; Dr. J. M. Cline, Galveston, Tex.; Mr. George E. Hunt, New Orleans, La., and Prof. P. H. Mell, Auburn, Ala., merit special mention for their many favors.

While on a trip through northern Texas for the purpose of making special observations, much depended upon the assistance of observers in that section. It is a source of much satisfaction to state that no delay was experienced at any point, and that the work was facilitated in every way possible. At Mesquite, Tex., Messrs. S. G. Lackey and T. P. Worthington gave valuable information concerning their localities,

as did Mr. A. A. Pittuck, of The Texas Farm and Ranch, and Mr. F. Doremus, of the Dallas *Morning News*. At Arlington, Tex., similar courtesies were received from Dr. L. C. Page, Mr. C. F. Mercer, Capt. M. J. Brinsan, Col. J. A. Ditto, and Hon. J. W. Hammack.

Among those who by correspondence contributed freely of their experience, Messrs. S. B. Mullen, of Harrisville, Miss.; Jeff. Welborn, of New Boston, Tex.; John C. Edgar, of Duval, Tex.; Hon. George J. Twiley, of Holly Springs, Miss.; Prof. H. A. Morgan, of Baton Rouge, La.; Prof. J. G. Lee, of Calhoun, La., and many others, have my sincere thanks. Grateful acknowledgments are also due to Mr. Henry Hotter, Secretary of the New York Cotton Exchange; Mr. Henry Hester, Secretary of the New Orleans Cotton Exchange, for many favors, and to Mr. A. B. Shepperson, of New York, for "Cotton Facts" and general statistical information.

HABITS AND NATURAL ENEMIES OF THE BOLL WORM.

DESTRUCTIVENESS.

During May corn is practically the only abundant and available crop to be attacked by the Boll Worm. At that time a study of a number of corn fields on both bottom lands and uplands was made. The number of plants attacked was noted, as well as other data, as shown in Table I.

TABLE I.—*Ravages of Boll Worm on May corn.*

	Field.								Total.
	1.	2.	3.	4.	5.	6.	7.	8.	
Plants examined	377	296	472	720	422	496	511	368	3,662
Eaten	16	7	12	21	4	6	16	15	97
Not eaten	361	289	460	699	418	490	495	353	3,565
Worms	3	4	1	7	......	......	3	8	26
Half grown	2	1	1	2	......	......	1	......	7
Very young	1	3	......	5	......	......	2	8	19
Color:									
Dark	3	1	......	5	......	......	2	7	18
Green	......	......	......	1	......	......	......	......	1
Light green	......	3	1	1	......	......	1	1	7
Mashed:									
Half grown	2	1	1	2	......	......	1	......	7
Very young	1	3	......	4	......	......	1	7	16
Not mashed	......	......	......	1	......	......	1	1	3

It will be seen from this table that of the 3,662 plants examined, 97, or 2.6 per cent, showed injury, and 26, or 0.7 per cent, actually contained Boll Worms. Fields 5 and 6 were "hill country," and though plants were found apparently injured by Boll Worms, much of the damage done was due to *Prodenia lineatella*. The other fields were Red River bottom lands.

June 1 a study was made of a small patch of sweet corn, which was then in good roasting ears. The results are given in Table II.

TABLE II.—*Ravages of Boll Worm on sweet corn roasting ears.*

Ear.	Worms.	Size.			Color.			
		Grown.	Half grown.	Very young.	Dark.	Green.	Light green.	Rose.
1	6		3	3	6			
2	3		2	1	3			
3	2	2			1		1	
4	6	2	2	2	4		2	
5	3		1	2				
6	1	1					1	
7	5		3	2				
8	3	1	1	1	1		1	1
9	4			4				
10	3		1	2	2	1		
11	1			1	1			
12	1		1					
13	*12		3	*9	5	1	5	1
14	5		2	3	2		3	
15	6		3	3				
16								
17	2			2	2			
18								
19	1			1	1			
Total	64	6	22	36	28	2	13	2

* One dead.

On the same date a field of crop corn just tasseling was similarly studied. The number of plants examined is not given, but simply those upon which worms were found. The larvæ in nearly every case were found in the freshly protruded or protruding tassel. The facts are presented in Table III.

TABLE III.—*Worms found on tasseling corn.*

Plant.	Worms.	Size.			Color.			
		Grown.	Half grown.	Very young.	Dark.	Green.	Light green.	Rose.
1	1	1						1
2	3	2		1	2	1		
3	1	1				1		
4	2	1	1		1			1
5	2		2			1		1
6	1	1				1		
7	2		2		2			
Total	12	6	5	1	5	4		3

Much error prevails among planters as to the causes of the shedding of the cotton crop, and that much of the blame has been misplaced is shown by the following tables. The data upon natural shedding (Table IV) and the natural or normal average number of bolls matured by a cotton plant under favorable conditions (Table V) were noted in fields entirely free from Boll Worm ravages.

TABLE IV.—*Bolls in cotton plant—natural shedding.*

Plant.	Bolls in plant.	Shedding.		Total.
		Natural.	Other causes.	
1	71	25	22	118
2	16	16	17	49
3	157	52	16	225
4	68	36	3	107
5	26	30	4	60
6	70	33	10	113
Total	408	192	72	672
Average per plant	68	32	12	112

TABLE V.—*Matured bolls in cotton plant.*

Plant.	Bolls matured.	Plant.	Bolls matured.
1	25	9	12
2	16	10	17
3	18	11	22
4	26	12	31
5	25	13	33
6	22		
7	22	Total	286
8	17	Average per plant	22

Table IV shows that when examined September 7 plant 3 had borne a total of 225 and plant 4 a total of 107 squares, forms, and bolls; September 29 plant 3 bore only 98 bolls and forms, and plant 4, 59; October 10 plant 3 had 96 and plant 4, 51; November 14, plant 3 bore 83 and plant 4, 44. At this time it was evident that the bolls yet remaining would mature and open if conditions continued favorable. Hence, by natural agencies the original numbers had been reduced to 83 and 44, respectively, by November 14. The shedding of plant 3 was, therefore, 63.2; that of plant 4, 58.9 per cent. Even the figures given in Table IV on September 7 show that of a total of 672 bolls and squares originally borne by the six plants only 408 were then upon them, a shedding of 264 bolls, or 39.3 per cent. The plants examined were above the average in growth and vigor.

These facts should impress the planter reporting damages supposed to be due to an insect with the necessity of making a careful examination and discovering the real causes operating. If this be done, he will often find that much of his loss is due to perfectly natural causes and not to insect depredations.

The data contained in Table V are based upon average plants which had already matured, or at least had set their full crop. It must be noted in this connection that the average given applies to good cotton only, in such districts as northern Louisiana and Mississippi. In river bottoms, where cotton grows much more vigorously, the average per plant is proportionally greater. In some of the southern and central

portions of Texas, where cotton grows from 7 to 10 feet high, the average may be twice that given in the table. These facts are recited to illustrate the necessity of making local studies for a given locality in order to arrive at anything like an accurate estimate of the injury and loss for that locality.

TABLE VI.—*Condition of cotton field at Mesquite, Tex.*

Plant.	Bored.	Other causes.	Good bolls.	Total.
1	15	....	7	22
2	4	14	15	33
3	5	18	16	39
4	2	2	14	18
5	1	4	58	63
6	3	....	8	11
7	12	....	12	24
8	14	3	6	23
9	6	....	7	13
10	10	....	2	12
11	6	3	12	21
12	21	5	18	44
13	7	2	21	30
14	3	2	14	19
15	2	2	21	26
16	1	4	22	27
17	....	9	33	42
Total	112	69	286	467

TABLE VII.—*Condition of cotton field at Arlington, Tex.*

Plant.	Bored.	Other causes.	Good bolls.	Total.
1	7	5	11	23
2	1	5	25	31
3	1	....	21	22
4	1	1	12	14
5	1	3	25	29
6	12	14	23	49
7	....	5	30	35
8	3	2	15	20
9	9	1	22	32
10	8	6	16	30
11	1	2	13	16
12	7	5	14	26
13	2	....	11	13
14	4	2	15	21
15	13	9	12	34
16	23	15	43	81
Total	93	75	308	476

TABLE VIII.—*Early and late cotton compared.*

LATE COTTON.

Plant.	Bored.	Other causes.	Good bolls.	Total.
7	12	....	12	24
8	14	3	6	23
9	6	....	7	13
10	10	....	2	12
11	6	3	12	21
12	21	5	18	44
13	7	2	21	30
Total	76	13	78	167

EARLY COTTON.

14	3	2	14	19
15	2	3	21	26
16	1	4	22	27
17	0	9	33	42
Total	6	18	90	114

Tables VI and VII exhibit data obtained while on a trip through the part of Texas which was worst infested by the Boll Worm. The figures for Table VI were noted at Mesquite, August 24, and for Table VII the facts were obtained at Arlington, August 27. In Table VI plants 1 to 6 inclusive were in the same field and stood consecutively in a row; plants 7 to 13 inclusive in a second field, consecutively as before; while plants 14 to 17 inclusive were taken at random in a third field. Plants 7 to 13 were in a field of late cotton, still blooming profusely at the time of observation; 14 to 17 were in one of early cotton in which all the fruit had set and which, therefore, contained but few blossoms at that time. These data are compiled separately in Table VIII for the purpose of comparison. It presents some significant facts concerning the question of early and late cotton in Boll Worm districts. Thus, of a total of 167 bolls of the late cotton, 76, or 45.5 per cent, had been injured by the Boll Worm; of a total of 114 bolls of early cotton, only 6, or 5.2 per cent, were injured. Estimating the difference upon the basis of the normal average, we have the following result: The seven plants of late cotton averaged 11.14 bolls per plant, and the four plants of early cotton 22 per plant, 22 being the normal average arrived at in Table V. The late cotton therefore shows a loss of 50.6 per cent, while the early cotton shows no real loss. This may be taken as an extreme case, but the general principle remains that late cotton receives by far the greater portion of the Boll Worm attack, virtually protecting the early cotton fields about it.

TABLE IX.—*Shed bolls found on ground.*

Table.	Plants inclusive.	Bored.	Other causes.	Total.
VI........	1-6 and 17	8	103	111
VI........	7-13	69	44	113
VI........	14-16	10	42	52
VII	1-9	40	44	84
VII	10-16	43	64	107
Total ..	....	170	297	467

TABLE X.—*Good bolls per plant.*

Source.	Bored.	Other causes.	Good bolls.	Total.
Table VI .	112	69	286	467
Table VII	93	75	308	476
Table IX .	170	297	....	467
Total..	375	441	594	1.410
Per cent ..	26.6	31.3	42.1	100

Table IX presents a study of the bolls and squares found shed and on the ground under the plants recorded in Tables VI and VII.

The totals of Tables VI, VII, and IX are arranged for convenience in Table X. From the facts thus presented it is found that 18 is the average number of good bolls per plant. The normal average has already been given as 22. Hence the loss from injury is 18.2 per cent instead of 26.6, as found by the usual method. This difference is largely due to having included the data of Table IX, which represents the shed bolls found on the ground under the plants examined. As has been shown by Table IV, many of these would have been shed by natural process, but were bored before having fallen. Hence, if included, they exaggerate the real damage. The actual damage should be estimated upon the basis of the average amount normally matured by the cotton plant in any given locality under favorable conditions. Omitting Table IX from Table X we have the following results:

Source.	Bored.	Other causes.	Good bolls.	Total.
Table VI	112	69	286	467
Table VII	93	75	308	476
Total ...	205	144	594	943
Per cent	21.7	15.3	53	100

The above percentages are obtained upon the basis of what was actually found upon the plant August 27, without reference to the number of bolls normally matured per plant for that locality. The per cent of damage is shown to be 21.7, which, compared with the 18.2 per cent obtained on the other basis, shows that this estimate is quite accurate and, for all practical purposes, satisfactory.

The damage detailed above was found only in the worse infested districts visited. In other localities the injury was much less, or none at all. Even in the infested districts some fields were found which had practically escaped injury. The estimated damage of 18.2 per cent applied more especially to a region approximately included by an imaginary line running from Paris, Texas, to Tyler, to Palestine, to Temple, to Greenville, to Paris. Other cotton-producing counties in Texas were much less affected, and for the entire State it will be safe to place the maximum limit of Boll Worm injury at 10 per cent, with probabilities that it is still less.

Along the Red River and Mississippi valleys, and, in general, in the bottom lands along the smaller rivers and creeks, the injury is greatest. In the greater portion of Louisiana and Mississippi the damage is certainly not over 2 to 3 per cent. In Arkansas the damage along the rivers and in a belt across the State from Little Rock to Fort Smith was more serious, and for a considerable portion of the State ranged from 10 to 15 per cent. This is due in part to the greater acreage of corn in proportion to that of cotton. The reason for this lies in the fact that a greater number of individual ears are produced, and hence the probability of a greater number of worms reaching maturity. The relation existing between the acreage in corn and the acreage in cotton is no objection to the trap-corn method, to be subsequently discussed, but rather makes it all the more advisable to use it at the proper time. In Alabama, Florida, Tennessee, Georgia, and the Carolinas the ravages are insignificant, and usually do not excite general attention. If the acreage and production of these States be included to ascertain the per cent of loss to the entire cotton crop from Boll Worm depredations, it is evident that the percentage will be reduced to a small figure.

Those who have never spent a season among cotton-planters may consider this discussion of damage peculiar or even unnecessary. The fact is that the average observer, whether planter or newspaper reporter, seldom comes to his conclusions upon a basis of what is found upon the plant, or after having considered natural causes of loss. He judges mostly by what he sees lying upon the ground, and to this, as has been shown, several causes contribute. Upon this basis (see Table IV) a damage of 39.2 per cent could be reported. Such reports are entirely misleading and erroneous, and have no foundation in fact. It is even more difficult to give an estimate of the damage to corn by Boll Worms. From Table I it is found that in May, 2.6 per cent of the young corn plants had been attacked. The plants were not ruined nor even checked in their growth, and ultimately produced sound ears of corn. The conditions presented in Table III are quite disgusting when viewing the ravaged tassels, but in the end the ear of corn is produced. Romantic discussions of these facts have been entirely misleading, and for corn it is safe to assert that no real damage is occa-

sioned, so far as the ultimate yield is concerned, by the depredations mentioned. The ravages in the ear at a later period do, however, occasion some loss. From a money standpoint this loss is perhaps felt most by gardeners growing sweet corn for early market. Badly infested ears must be thrown away and a greater acreage is therefore necessary to insure a sufficient supply of uninfested ears. How serious a matter this may be depends entirely upon the locality, and much the same may be said of the regular crop. Many of the ears have some of the grains damaged, and this, together with the excrement of the worms, makes them to a certain extent distasteful or undesirable for feeding purposes. But the most serious objection arises when the corn comes to the mills to be ground into meal. Technically the meal will be reduced in purity and standard quality, but this is after all only a theoretical objection, since the question is never raised or thought of when the meal is on the market, and its market value is not affected.

General estimates of insect injuries by per cents are misleading, and hence the advisability, in order to maintain scientific accuracy, of assigning to them only a local application or significance.

FOOD-PLANTS OTHER THAN COTTON AND CORN.

Tobacco.—The eggs of the Boll Worm are laid indiscriminately upon all parts of this plant. Tobacco leaves and very young portions of the plant are thickly set with plant hairs, which are covered with a sticky secretion. The eggs are usually found stuck fast to the tip of one or two of the hairs; not close to the surface of the leaf. The sticky hairs trap many small insects which crawl about them and even the newly issued Boll Worms are caught occasionally, and perish in the attempt to get away. The flower-buds and green seed-pods of tobacco are freely attacked, and large racemes sometimes have one-half or two-thirds of their fruit eaten into. Tobacco is topped to prevent its flowering and producing seed. The stem contains a succulent pith which the larvæ relish and they often eat down the stem from the broken and exposed end. As they go down, the leaf found at each node often withers and dies as they pass it. The small field of tobacco examined was several miles away from any cotton or corn fields. This partially explains the abundance of the Boll Worm in this isolated patch. They doubtless do not feed so extensively in regular tobacco districts. The important thing for the cotton-grower is to see that the topped portions, bearing so many eggs and young larvæ, are burned for the purpose of destroying them. The suggestion may be carried even further. The topping process practiced upon tobacco leaves only a minimum number of racemes for the production of seed. These remaining racemes were more thickly stocked with Boll worm eggs than anything else observed in Texas; in fact, nothing except fresh corn silk was ever found so thickly infested. This was on August 25, which is past the height of the flowering period of the earlier cotton. Small patches of cotton could therefore be planted

as trap crops, cutting off and burning the racemes when well stocked with Boll Worm eggs. In those portions of Texas which are subject to early and continued drought this method may be even more successful than that of trap corn.

Tomatoes.—The fruit of this plant is bored in the same manner as the cotton boll, as already discussed in Bulletin 24 of this Division. The worm also bores into the stems, sometimes cutting them nearly off in so doing. The damage is usually ascribed to cut-worms, and in the majority of cases, properly. Occasionally, after having eaten to the pith of the stem the larva goes downward, hollowing it out as it goes. This causes the portion of the plant above the point of injury to wilt or break and die. This sometimes happens to the central trunk of the plant and the whole of it is then ruined.

Other Food-plants.—Cowpeas and the pods of various kinds of beans and peas, are often found eaten full of holes, and the peas and beans devoured. Cucumbers, cantaloupes, and small watermelons, and okra pods are occasionally bored, but the attack is not general or extensive. Mr. W. J. Holland, Brewton, Ala., reports their boring into and feeding upon the stems of Collard. Red-pepper pods are occasionally destroyed. The wild Ground Cherry (*Physalis pubescens*) quite commonly has its berries eaten by this insect. In the vicinity of Mount Lebanon, La., Mr. T. W. Vaughan reports that during September fully one-half of the pods borne by the plants had been ravaged by it. Late in the season volunteer sorghum plants are often found with riddled leaves, some of which may be due to boll-worm attack, but in the majority of cases is attributable to cut-worms. A large Abutilon plant in an ornamental flower garden was freely deposited upon by Heliothis, nearly every flower bud and some of the leaves bearing an egg or two. The young larvæ did not relish this food-plant, and deserted it almost immediately. Probably the majority perished before finding suitable food. The leaves and very young flower buds of the Jamestown Weed (*Datura stramonium*) are sometimes eaten, as also the fruits of the Cockle Burr (*Xanthium strumarium*). The burs are attacked while very young and just forming, the usual method of injury being to eat into the tender peduncles bearing them. Some of the host-plants enumerated for the Boll Worm are doubtless accidental, for the larvæ do not thrive upon them.

CHARACTERS AND TRANSFORMATIONS.

These have been treated at some length in Bulletin 24 of this Division and only a few additional observations will be noted in this connection.

LARVA.

A marking not found in all specimens is a pinkish or pale orange colored spot on each segment at the upper edge of the subdorso-lateral stripe. The color may be inconstant for the same individual. For

example, a larva which was taken from a cornfield June 9, was uniformly green when placed with food in the breeding cage. June 12 it was noted as becoming yellowish, or at least could not be called green. Thus several color variations were noted during the larval state of the same individual. In most specimens the color remains quite constan.

TABLE XI.—*Proportion of light and dark larvæ.*

Source.	Date.	Light green.	Green.	Rose.	Dark.	Total.
Corn......	May 8	....	4	....	6	10
Do	May 9	6	17	....	10	33
Table	May 14–16	7	1	....	18	26
Do	June 1	13	2	2	28	45
Do	June 1	....	4	3	5	12
Total	....	26	28	5	67	126
		$\underbrace{\qquad\qquad}_{54}$		$\underbrace{\qquad\qquad}_{72}$		

Some facts relative to the proportion of light and dark-colored specimens are presented in Table XI. All the larvæ were taken from corn plants, tassels, and ears. Most of the green ones were about grown, the dark ones mostly small. The figures clearly show that for May and June the dark worms predominate, comprising about 57 per cent of the number. During July and August the proportion becomes about equal, while at the close of the season the light-colored specimens are in the majority.

The larvæ are very tenacious of life, as the following note will show: One evening an ear of corn containing a nearly grown Boll Worm was placed on end in a jar of water to keep it fresh until next morning. At that time the larva was found outside the ear in the water. To all appearances it was dead, and was so considered. Mr. Banks, however, placed it upon some dry earth in a saucer exposed to the direct sunlight, and the following day we found, to our surprise, that the larva was again becoming active. It was later provided with food, upon which it fed, pupating perfectly. To our disappointment, however, it died in the pupal state. Half-grown worms placed in the bud of young corn plants in breeding cages often bored the entire length of the stem to the roots. In several instances this left them an inch or two below the surface of the water in the vessel, but no harmful effects upon the larva were noted.

In attacking young corn the Boll Worm does not always feed in the the bud or heart of the plant, but occasionally takes a position on the outside of the stalk near the surface of the ground, eating inward as if into a boll. This done, the plant wilts and dies. When examined and found eaten nearly off, the injury is at once assigned to the work of cut-worms, and this is doubtless the true explanation in most such cases, but the exceptions should be noted. In the breeding cages, where young corn plants were kept fresh and growing in wet moss, a

larva in one instance left the plant and went entirely beneath the surface and fed upon the tender roots.

Many observations upon recently hatched larvæ in breeding cages proved that they feed reluctantly upon corn blades, except in the heart of very young plants. In their continued search for something better they nearly always perished. In the field very young Boll Worms are rarely found on leaves or husks, but always in the silks near the tip of the ears. This fact, taken in connection with laboratory observations, indicates that the larvæ hatched from eggs on the leaves and husks at once seek out the silks. Doubtless many perish before reaching the ears. They feed mostly upon the tender silks up to the time of the first molt, and later begin feeding upon the milky grains.

The larvæ sometimes come out from their ear of corn and either take position on the outside of that ear or go down to the stalk and there molt. Only a small number, however, have this habit, the majority molting without leaving the ear.

Upon cotton the newly hatched larva sometimes hides itself in a cluster of expanding leaf buds, fastens them together loosely with a few silk threads, and either feeds under the shelter of the young leaves or bores the peduncles and tender growing stems. So far as observed, this slight webbing occurs only previous to the first molt.

During spring and summer the Boll Worm undergoes its transformations more rapidly, and the intervals of molting are correspondingly shorter. The following record is an example:

Egg hatched June 11, 9 a. m. First molt, June 17, 9 a. m., six days after hatching. Second molt, June 18, p. m., or not more than one and a half days after the first. Third molt, June 20, two days after second. Fourth molt occurred at time of pupation, June 25, five days after the third. Length of larval state, fourteen and one-half days. The exact number of days between the molts varies slightly, but the general fact remains that the second and third molts occur in quick succession, while the first and last are often at much longer intervals. Before the first molt their growth is slow, but afterwards the rapidity of growth under favorable conditions is remarkable. During the period from the first to the third molts the larvæ feed incessantly from morning to night. Before the first and after the third molts occasional short intervals occur during which they may be found resting.

There is no question but that Boll Worms deliberately prey upon each other when they become numerous in ears of corn. Frequently an ear is opened and a larva found in the act of devouring another. These observations, however, had the objection that there was no record of the larvæ previous to the time of making them, and that therefore the victims might have been parasitized or diseased and unable to resist attack. Accordingly an ear containing three or four quite large Boll Worms was taken from the field and the worms were carefully examined as to parasitism or previous injury. They were then placed back

in the ear in a large breeding cage, care being taken not to excite the worms during the process. The second day following the ear was examined, and one of the larvæ was found feeding upon another, the third having been already devoured. This was a clear case, and no further observations were made upon this point.

PUPA.

When full grown the larva goes into the earth for pupation. The process of burrowing, making the cell, and pupating occupies about two or three days for the spring and summer weather. In October and November often ten days or two weeks are spent in the cell before pupating. The records of pupæ from some of the larvæ reared are tabulated for reference in Table XII.

TABLE XII.—*Record of observed pupæ.*

Number.	Pupated.	Issued.	Length of pupal state.	Color of larva.	Color of moth.	Earth.	Depth.
			Days.				
1	May 23	June 4	12	....	....	....	Surface ...
2	June 8	June 17	9	Rose....	Olivaceous........	Moist...	....
3	June 4	June 13	9	....	....do	...do	½ inch ....
4	June 8	June 17	9	Green...	Dark	Dry	....
5	June 8	June 18	10	...do	....do	Moist...	¾ inch ....
6	Missing.	June 20	....	...do	....do	....	⅞ inch ....
7	June 15	June 25	10	...do	Olivaceous........	....	....
8	June 25	July 6	11	...do	....	Moist...	1¼ inches .
9	June 15	June 24	9	...do	Dark	...do	....
10	June 22	July 2	11	...do	....do	Dry	Surface ...
11	June 26	July 6	10	Rose....	....	Moist...	....
12	July 17	July 26	9	....	Dark	(*)	....
13	July 13	July 24	11	Green ..	....	Dry	Surface ...
14	July 22	July 31	9	...do	Olivaceous	...do	....

* Wet moss.

The average length of the pupal state for the thirteen specimens recorded is ten days, with a range from nine to twelve days. For the months of May, June, July, and August this time is correct, but late in August, September, October, and November the length of the pupal state becomes variable. As an example of this variability may be recorded the following: Some eggs hatched August 26 and the larvæ fed until October 9, a larval period of forty-four days. October 9 two pupæ were obtained. One of these hatched December 12 of the same year, after a pupal stage of sixty-four days. The remaining pupæ issued May 1 of the following year, a pupal state of 203 days. In 1891 quite a number of larvæ pupated about the middle of October. Two-thirds of the number issued after a month, while some were kept over winter.

The manner of pupation is by no means constant. In the field the normal method is to burrow at an angle to a depth of 2 or 3 inches, then to form a cell upward from the end of the burrow. In this cell the pupa rests upon its posterior end in a vertical position. Loose earth sparsely webbed together partially fills the burrow for almost, if

not quite, its entire length. In breeding cages they sometimes pupate on the surface, either naked or by loosely webbing together some earth, making a frail cell. Sometimes the larvæ burrow straight down and pupate at the end of the burrow without forming any inclined cell. In one instance the worm simply remained in the ear upon which it had been feeding, formed a cell, and pupated.

During the summer months, at moderate temperatures, it seems to make little difference in the length of the pupal state whether the pupæ are on the surface, kept perfectly dry, or continuously moistened. Nos. 4, 10, 13, and 14 in Table XII were placed in perfectly dry earth to pupate, and kept dry up to date of hatching. The time was 9, 11, 11, and 9 days, respectively, or an average of 10 days. Nos. 2, 3, 5, 8, 9, and 11 of Table XII were placed in moist earth and moistened each day during the pupal state. Time was 9, 9, 10, 11, 9, and 10 days, respectively, an average of 9.6 days. No. 12 was placed upon a corn plant in a 6-inch flower pot, half full of moss, kept saturated with water so that when lifted it would drip. This was not intended for the worm to pupate in, but simply to keep fresh the plant upon which it was feeding. Unawares the worm went down into the wet moss to a depth of 2 inches, formed a cell, and pupated. The pupa was left in this cell, and the moss kept constantly wet to excess. Nine days afterward the moth issued. During the entire time the cell had not been broken into, and the pupa may not have been subjected directly to the excessive moisture. These facts are given for what they are worth, as bearing upon the claims made by some that either excessive rain or drought retards the development of the insect. Those kept perfectly dry were exposed to an average daily temperature of at least 95° F. Those kept constantly moist had about the same temperature. The results showed that practically no difference in the length of the pupal state existed. This, it must be remembered, applies only to the spring and summer months with high temperature. During the fall and winter, when decided changes in both moisture and temperature take place, simultaneously, their development is certainly retarded.

IMAGO.

The moth varies in color from a distinct olivaceous to a brownish hue. Some claim that a relation exists between these types of color in the imago and the colors of the larvæ. The records presented in Table XII bear directly upon this point. Nos. 4, 5, 6, 7, 9, 10, and 14, were green larvæ, and the color of the moths was dark, dark, dark, olivaceous, dark, dark, and olivaceous, respectively. Thus both types of color in the moth occur for the same color of the larvæ. It must be noted, however, that some of the pupæ named were kept perfectly dry, others wet or moistened continuously. On this point for those kept dry may be quoted No. 4, which is dark, and No. 14, which is olivaceous. For those kept moist, No. 3 is olivaceous and No. 5 is dark, both of which, also,

had pupated beneath the surface. This record, from the nature of the case, is entirely too limited to generalize from, further than to note that if any relation exists between the larval color and that of the moth there are exceptions. These exceptions prevail, also, for the conditions of dryness, moisture, and surface pupation in relation to the same question.

The numerous plants upon which the female deposits, together with her reckless habit of miscellaneous deposition, compels the wandering about of many of the recently-hatched larvæ which find themselves in unfavorable circumstances and perish in their search for more suitable conditions. The loss occasioned by this misdirected deposition accounts in part, as has already been noted, under the head of "Other Food-plants" for the small number of worms as compared with the number of eggs which a single female is capable of depositing.

When the females come out from their hiding places they confine themselves almost entirely to their host plants, either for feeding or for deposition. From the time of hatching to the end of the egg-laying period they are bent upon business whenever they appear, and their attention is not easily distracted. This fact becomes of great importance in the use of lights and poisoned sweets, and will be considered more fully subsequently.

The food habits of the moth are not injurious at any time or in any manner. Some planters assert that in depositing their eggs they puncture the squares and forms, causing them to drop. The fact is that the ovipositor of the female is not strong enough to perform such an act, and, furthermore, the eggs are laid on the surface.

NUMBER OF BROODS AND HIBERNATION.

At Shreveport the first brood of larvæ resulting from imagos which hatched from hibernating pupæ matures about June 1. The second brood begins to appear about the 10th of June. The larval state of the first brood is about fifteen days, and the pupal state about ten days. For the third and fifth broods the time is more variable and the pupal state may run from fifteen days to over a month, or the entire winter. The majority of the fifth brood of pupæ pass the winter as such, though a few issue before the season closes and hibernate as moths. These hibernating moths appear and begin depositing much earlier than, and make a troublesome confusion of broods with, those resulting from hibernating pupæ. This, together with the fact that Boll Worms—many quite young—can be found at Shreveport, La., as late as November 20 justifies the statement that for that locality, beginning in the spring with the few hibernating moths, we have a series of small broods along with the regular ones, the former producing a sixth brood which hibernates in the pupal state, the latter only five broods of which a few of the last hatch and hibernate as imagos. This mixing of broods explains why full-grown larvæ and newly-hatched ones are found simul-

taneously at any time after the middle of May. The winter of 1890–'91 was unusually mild in Lousiana, and the spring proportionately earlier. Hence the above dates may not be average or normal, and, in any case, are intended to have only a local application.

The foregoing discussion is based upon observations made in northern Louisiana and Mississippi. In northern Mississippi the evidences of a portion of the last brood hibernating as imagos are more meager and less conclusive. In Arkansas the reports of observers and the time of greatest depredation seem to point conclusively to the fact that all of the last brood hibernate in the pupal state, while from the fact that the spring is later than further south, their habits of hibernation are more constant, the first brood issuing more evenly and all the broods being better defined. The fall season is also more severe, if not earlier, and hence only the five broods occur in the cotton-producing portion of the State. In the remainder perhaps only four full broods occur, with an incomplete fifth one. On the contrary, in southern Texas the winters are mild and the spring comes much earlier than in the cotton region of Louisiana or northern Texas. From constant communication with cotton-planters and other observers in southern Texas, it was determined that there could be no doubt about the hibernation of a considerable portion of the last brood as imagos. These appeared and began depositing earlier than at Shreveport, certainly producing six distinct broods and a partial seventh by the close of the season. Those issuing from pupæ in spring produced six well-defined broods.

Failure to take into consideration these geographical and meteorological differences over so vast a territory as the culture of cotton occupies has resulted in great confusion and much controversy among cotton-planters as to the number of broods and the times of their appearance. The truth probably is that each is correct for his own district. The determination of the time of appearance of the several broods of moths and when their egg-laying is most abundant is a matter of great importance in intelligently managing the trap-crop method for protecting the cotton, and will be further discussed hereinafter.

PARASITES.

On June 15 specimens of *Pteromalus puparum* obtained from *Pieris rapæ* in great numbers, were placed with a large Boll Worm upon earth in a wide-mouthed bottle. As both males and females of the parasites had been placed in the bottle, some were seen copulating later. The parasites frequently alighted on the back of the larva. The worm, opening its jaws, would quickly and violently throw its head and the anterior part of its body around to the point where the insect sat, and often captured it. This was not merely accidental, for the process was often repeated and a micro was nearly always captured. Once in the jaws of the larva, the parasite was quickly eaten. Before pupation, June 19, the larva had in this manner eaten about thirty of the forty or fifty parasitic in-

sects with which it had been confined. June 29 the pupa hatched. The parasitic adults therefore had failed to deposit any eggs upon the larva, or, if so, the eggs had failed to hatch.

EGG PARASITES.

On June 3 *Trichogramma pretiosa* Riley was found quite plentiful in some localities. Parasitized Heliothis eggs were placed in a vial for the purpose of rearing the imagos. On June 4 some had issued, and a female was observed in the act of depositing her eggs. She first made a careful examination of each part of the egg. Selecting a certain point, she took a firm hold on the egg with her legs, elevated the head and thorax, bringing the entire weight of the body to bear on the end of the ovipositor. Then, by a series of drilling motions, the shell was punctured and the egg deposited. During the entire process the antennæ were kept perfectly quiet and folded down upon and over the vertex. The act of deposition occurred three times in ten minutes.

On July 6 plenty of Heliothis eggs were again found on the silks of trap corn, and many of them were parasitized. Concentrating the deposition of the Boll Worm eggs upon the trap corn greatly increases the opportunities of the parasites for depositing in them, and the benefit derived from it in this way is very great.

A second parasite was reared from Boll Worm eggs. It is somewhat larger and much darker than *Trichogramma pretiosa*, but does not occur in nearly so great numbers. The specimen was referred to Dr. Riley for examination. He found it to be an unnamed species of the genus Telenomus.

PARASITES OF THE LARVA.

Euplectrus comstockii and *Chalcis ovata*, whose life-histories and peculiar habits have already been noted in the Fourth Report of the United States Entomological Commission, have been reared from the Boll Worm. The specimen from which *Chalcis ovata* was reared also contained many larvæ of *Phora aletiæ*. From these numerous specimens of *Hexaplasta zigzag* were reared. It seems strange, however, that only a single specimen of *C. ovata* and two or three of *P. aletiæ* should be obtained from the worm. The explanation, if any, must be that *H. zigzag* parasitized the larvæ of both.*

Another beautiful parasite is a species of Limneria, which was mostly found in the early part of the season, one from a Boll Worm taken from corn and another from a tomato vine: the former in May, the latter in June. The parasitic larva issues from its host and spins a peculiarly marked white cocoon with brownish or reddish spots arranged in regular order.

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* The supposition that the Hexaplasta could have parasitized the Chalcis larva is undoubtedly unfounded.—C. V. R.

A large Dipterous parasite was often reared from Boll Worms. They most frequently attack them later in the season, as only at that time were they obtained.

OTHER NATURAL ENEMIES.

Boll Worms were scarce in cotton at Shreveport, and the studies which had been planned for determining the relation of birds to this insect could not be made. Accordingly only a few statements from correspondents will be given on the subject. Prof. H. A. Morgan, of Baton Rouge, La., in a letter of June 6, states that "sparrows have been noticed to feed upon them occasionally." Later a letter was received from Mr. S. B. Mullen, Harrisville, Miss., in which he stated that sapsuckers alighted upon the ears of trap corn and ate about half of the Boll Worms found in them. Mr. Mullen was then requested to shoot a number of the birds, extract their crops and stomachs, and forward them for study. He experienced some difficulty about mailing alcoholic material, and hence made the examinations himself. He reported that numerous heads of Boll Worms were found in the stomachs and some small Boll Worms in the crops.

Since then, through the kindness of Mr. W. B. Barrows, of the Division of Ornithology and Mammalogy, it has been determined that the species in question is really not a true sapsucker, but probably the Hairy or Downy Woodpecker, both being known to be insectivorous.

ANTS.

In spring and early summer larvæ in general are not so abundant, or at least the Boll Worm in young corn in rather isolated fields is more accessible than many other larvæ. It is during this period that the attack by ants is most frequently noted. About June the larvæ of other species become numerous, plant-lice are met with everywhere, and the attack by ants becomes so divided that it not only appears to be of less economic importance, but requires constant close watch to witness an ant-boll-worm tragedy. Failure to consider the season doubtless accounts for the difference of opinion expressed by planters and other observers.

Before corn begins to silk and put forth ears, and to a certain extent during and after that time, ants freely attack any larvæ they may find crawling about on the ground or upon corn plants.

There are two species which are specially antagonistic in temperament, and these are the ones upon which most of the observations are made. One is *Solenopsis geminata* Fabr. and the other *Dorymyrmex pyramicus* Roger. For example, June 1 a full-grown Boll Worm on a corn plant was teased until it dropped to the ground. In a moment a small ant (*Dorymyrmex pyramicus*) pounced upon its back and could not be dislodged by the most violent and promiscuous rolling and jerk-

ing of the larva. After a short interval three other ants arrived and joined in the attack. After about five minutes the larva had been exhausted by its violent tumbling, and was perfectly helpless when dragged away. A second larva, more than half grown, was later dropped on the ground near by. It began to travel, but soon crossed the path of another species of ant (*Solenopsis geminata*). At once one pounced upon it, when the larva began rolling in the dust and loose earth, but failed to dislodge its enemy. After a few minutes, other ants came to the assistance of the first until about half a dozen were engaged in the work of biting and tormenting. The larva was soon exhausted and completely at the mercy of its enemies.

In August and September such attacks are rarely witnessed, and larvæ can even be thrown in the path of these ants without danger of attack in every instance. When not hungry, or soon after they have had a fight with a Boll Worm, observation reveals the ants touching the larvæ or even running over them without making an attack.

June 10, on ears of corn, the ants were seen attacking Syrphid larvæ, probably *Mesograpta polita*. They simply picked the larvæ up in their jaws and carried them down the plants to their burrows. July 1, ants were observed feeding upon Syrphid pupæ of probably the same species as above noted.

June 1, ants (*Solenopsis geminata*) were seen at a hole in the husks of an ear of corn. The husks were carefully removed without disturbing the ants. They were found feeding upon the liquids of a recently killed half-grown Boll Worm. The ear being well stocked with larvæ, the injured one had doubtless been killed by another of its own species, and while devouring it the victor was probably disturbed by the ants and abandoned its morsel for the benefit of the intruders. Subsequent persistent observation verified this surmise and showed that the ants seldom directly attack and kill a Boll Worm in the ear. It has already been explained that the Boll Worm has a natural tendency, when crowded or provoked, to feed upon its own species. The ant has learned to know that infested ears of corn are an excellent source of supply for juices and they are found most plentifully in those ears. After entering, the best portions are selected, the little surveying which this requires bringing them into contact with the Boll Worm. This living thing seems to excite them and they begin to bite and tease it until it becomes enraged and attempts to get away. In doing so the larva bites to the right and left and kills many of the smaller larvæ which it happens to meet. The ants are very fond of the blood which oozes from the wounds of the injured larvæ, and at once proceed to feast upon it. Should the injured worm in its weakened condition attempt to get away the ants soon overpower it. The first worm, however, having once had a taste of blood, continues its depredations upon the slightest provocation, and, as would seem from breeding-cage observations, is, for a short time and if opportunity offers, often inclined to

feed in this way rather than in the usual one. Whether the ants do their teasing in the hope of inducing boll-worm fights, or only to drive out the larvæ so as to have full possession of the ear, the fact remains that in either case their actions are often responsible for the cannibalism which occurs among the Boll Worms in the ears. The ants seem to prefer the fresh juices of grains of corn yet in the milk to those found in the excrement of Boll Worms or the decaying grains which have previously been eaten into. In order to enjoy the freshest juices, however, they must first drive the Boll Worms from the point. It would seem, therefore, that the cannibalism in ears of corn due to the behavior of the ants is probably more incidental than intentional. The importance of their actions, however, is not to be underestimated. Their teasing process does not need to be repeated for each Boll Worm found in an ear. When a large Boll Worm is once thoroughly provoked in this manner it often goes to every part of the ear, and wherever another larva is found a fight ending in a dead Boll Worm is quite certain to follow. This may continue until only one remains, or it may go only to the extent of killing a few at that time. The slightest provocation within a reasonable time thereafter seems to be sufficient to start the exterminating process again. One such provocation by ants, therefore, often suffices to clear an ear of all Boll Worms but one. It should be borne in mind, however, that crowded conditions where the larvæ encroach upon each other furnish the same provocation for fighting. Cannibalism among Boll Worms, therefore, is not the result of a single agency, but of several, which directly or indirectly contribute to bring about the result.

WASPS.

The large red wasp, *Polistes rubiginosus*, so common in cotton fields, carries off the larvæ of many species found feeding upon cotton, and doubtless takes a Boll Worm occasionally when they are present. *Polistes bellicosa*, *P. perplexus*, *P. gluerosa*, *P. annularis*, *Pompilus atra*, *P. americana*, *P. philadelphicus*, *Priocnemis fulvicornis*, and *Chalybion cœruleum*, are all common in cotton fields, and doubtless capture Boll Worms, as well as other larvæ.

OTHER INSECTS.

Other insects which are known to be carnivorous are often found abundant on corn silks and infested plants. Notable examples on corn silks are *Scymnus collaris* and *S. cervicalis*. These two species probably puncture or eat into the Heliothis eggs found upon the silks.

Two species of Robber Flies (*Erax lateralis* and *Deromyia* sp.), were observed catching Boll Worm moths on the wing.

Metapodius femoratus is frequently found preying upon the Boll Worm. The young seem to be especially beneficial in this respect. Unfortunately the eggs of this species are attacked by an egg parasite which

breeds in them in great numbers. This is an undescribed species of the Chalcidid genus Encyrtus.

Geocoris punctipes attacks the small Boll Worms and the Spiny Soldier-bug, *Podisus spinosus*, has often been observed at its beneficial work.

August 24, at Dallas, Tex., upon tobacco plants well stocked with eggs of the Boll Worm were found great numbers of the young and adults of a species of Dicyphus. By counting a number of eggs which were shriveled and evidently dead, it was determined that about 5 per cent were in this condition. The Dicyphus was the only insect found plentiful upon the plants, and it seemed reasonable to conclude that to it was due the puncturing of the eggs. After long and patient watching it was finally found that they really did the work.

Triphleps insidiosus punctures the eggs of Heliothis and sucks their contents. The egg-shells appear slightly shrunken and shriveled afterwards. From continuous observation one is forced to realize that no small per cent of the eggs is destroyed in this way. The empty egg-shells are met with in almost every observation. Mr. Banks, who made most of the observations upon this insect, estimates that probably 10 per cent of the eggs are destroyed in this way. From my own studies I am convinced that the estimate is none too large. This insect preys also upon its own species, at least in confinement. Four specimens, collected from cotton, were placed in a vial for subsequent study, and several hours later one was found with another impaled upon its beak.

These small insects are commonly found behind the involucres of squares and bolls and are very abundant in corn silks. Here the Heliothis eggs are most numerous and afford the Triphleps a good opportunity to feed upon them. The young and pupæ are small, wingless, pale or often bright red, and could readily be mistaken for the young of the Chinch Bug in general appearance, though they are shorter and more triangular in shape.

No spiders were ever observed in the act of devouring a Boll Worm, but several species, very common upon cotton plants, have been so constantly observed destroying other insects found there that probably the reason why no Boll Worms were taken is because they were scarce. The following observations upon some of the more carnivorous species may be recorded: *Phidippus tripunctatus*, devouring a Syrphid (*Mesograpta polita*) upon corn September 25; same species upon cotton bolls October 11 and 13. *Chriracanthium inclusum* on young bolls. *Anyphæna gracilis* from corn silks. *Dendryphantes nubilus* and *D. octavus* from cotton bolls, the former devouring a plant-louse. *Peucetia viridans* and *Runcinia aleatoria* on bolls, the former devouring a large Dipter.

INSECT RAVAGES MISTAKEN FOR THOSE OF THE BOLL WORM.

Thecla pœas.—The larva of this insect bores cotton bolls just as does the Boll Worm. Occasionally it eats a hole into the young portion of

the thick main stem or at the juncture of the peduncle with the stem. The larvæ when young are almost entirely whitish, but as they become more mature they turn to a livid green. Every larva collected during the season was parasitized and failed to mature. In one instance a small Hymenopter was bred. In another a Tachinid was reared. The parasitic larva issues from the body of its host near the head. A nearly grown Thecla larva was found at Shreveport as early as July 1, another at Curtis July 3, and a very young specimen at Briar Field July 25. The distance between Curtis and Briar Field is about 40 miles, showing that the species is well distributed and that the observations on cotton were not exceptional cases. Mr. Mullen, of Harrisville, Miss., also reports this species feeding upon beans and corn in his locality.

Prodenia lineatella.—In confinement the larva feeds almost exclusively upon the young bolls and squares, showing that these insects have the genuine Boll Worm habit. The very young larvæ are quite light-colored, and in May and June are often found in the buds of young corn plants, feeding as does the Boll Worm. The mature worms have a distinct velvety black appearance, with a narrow yellow line dorsally and a whitish triangular patch on the front of the head. In September this species was received from Mr. C. F. Yarbrough, Camden, Ark., as feeding in broom corn.

Platynota rostrana.—The head of the larva is reddish or black and a similarly colored calloused patch dorsad of the first segment. Body pale greenish, slightly hairy. In the fields upon cotton plants or when placed in breeding cages, they freely attack and bore into young bolls, feeding upon their contents. July 8, one pupated between a fold of the involucre which had been carefully fastened together by silk threads. July 13, a second larva pupated. July 15, the first pupa hatched, the second on July 19, the pupal state therefore being seven and six days, respectively.

During April, May, and June several species of larvæ ravage in the buds of young corn, exactly as does the Boll Worm, and many are not easily distinguishable from the darker Boll Worms.

Agrotis ypsilon.—The larvæ of this species were collected from corn April 20. These larvæ are at times cannibalistic. In breeding cages a large specimen was observed devouring a younger one of its own species.

Laphygma frugiperda is abundant upon trap corn in June and July, and many planters had mistaken them for Boll Worms. One specimen of this species was taken from corn July 10 and July 29.

Baris æræa Boh., was found November 21, eating a small hole into the peduncle of a young boll. The small, round hole could not be distinguished from the injury occasionally done by the young Boll Worms.

Parajulus impressus Say is occasionally found between the involucres and young bolls during September and October. They sometimes feed at the base of the boll, causing it to drop, and leaving a black spot much the same as when a Boll Worm starts to enter, but deserts it without further injury.

Calocoris rapidus.—This Capsid is very common upon cotton plants, and is usually found between the involucres and bolls. Its damage is done by puncturing the bolls with its beak. This leaves a small, round black dot at the point of the puncture, and this is the mark so often attributed to the moth of the Boll Worm. The injury nearly always has the effect of causing the boll to "flare" and drop, or if not, then the tuft of cotton in that section of the boll becomes stained. *Largus cinctus* proceeds in the same manner as *Calocoris rapidus*, leaving the characteristic puncture upon the fruit.

Homalodisca coagulata.—This leaf-hopper can be found quite common upon cotton plants from the 1st of June. Earlier it is found most abundant upon the young growth of poplars along the bayous about bottom-land cotton fields. Though common upon cotton it seems to prefer to feed and breed upon the new growth of the trees just mentioned so long as it remains fresh and growing. Nevertheless, it does considerable damage to cotton both by its habits of feeding and those of egg deposition. The female possesses two cutting serrated or saw-like blades, which fit together and form the ovipositor. With this she makes punctures for the reception of the eggs. To do this she leaves the central stem where the adults are usually found and locates among the tender growing portions, especially young "forms" or "squares." The act of deposition was twice observed on the involucre or "ruffle" of these portions. The female braced herself upon all legs, the head and anterior portion of the body elevated. The very thin pointed ovipositor was then exserted, and by a forcible sawing-like operation was gradually inserted underneath the epidermis. The channel was made concave, the distal end almost coming to the surface again. The long, slightly curved, cylindrical white egg was then introduced and the ovipositor withdrawn. The time occupied by this process was about one or two minutes. After a short interval a second egg was laid in like manner alongside of the first but slightly in advance of it. A few hours after deposition, slight, pale, blister-like swellings were noted over the points where the eggs were found. One egg was dissected from the leaf and saved as a reference specimen. Unfortunately a larva of *Thecla pœas* was temporarily placed in the same bottle as the form in which the remaining egg was found. When next observed the Thecla had eaten a hole directly through the portion in which the egg had been deposited, and the latter was therefore destroyed. As a result, the duration of the egg state could not be determined. The eating of the egg by Thecla was doubtless only a coincidence. The recently hatched larva is entirely whitish, and keeps hidden among the very young leaves or the involucres of "forms" and small bolls. The very young carry the abdomen elevated almost at right angles with the body. They feed by puncturing the epidermis at the base of the flower bud, or the very young boll, or quite frequently proceed to the short, tender peduncles. Soon after this injury is done the form or small boll will "flare," turn pale, and drop off. If examined when

about to drop off, a small roundish black spot will be found upon the peduncle, the base of the form, or boll. These markings the planters designate as "sharpshooter" work, many attributing it to the Boll Worm, others to the young Boll Worm, and occasionally an observing planter is found who truthfully assigns the injury to some insect other than the Boll Worm. The other extreme of intelligence is also found which stoutly maintains that this small leaf-hopper is the real Boll Worm "fly."

The young become gradually darker with each molt. When half grown they are quite bluish or lead-colored, with distinct wing-pads. At this age they begin to run about the plant more, and as they become still more mature are often found on the central stem. Previous to that time they confine themselves quite closely to the tender, growing parts of the lateral branches. When disturbed they at once rush down to the central stem, run up at first, then if still pursued, down again, dodging from side to side until they feel that they have escaped, when they stop and rest, head downward.

The imago is brownish, sometimes tinged bluish, or in older specimens faintly reddish. Fresh females often have a white powdery spot on the middle of the fore wings. This spot rubs off easily and is not apparent after a time. The adults make a distinct buzz in their short flight from plant to plant. They feed usually upon some part of the central stem. When feeding they rest head downward and puncture the bark with their beaks. While feeding or resting in this position they incline the tip of the abdomen outward, often throwing off some half dozen drops of liquid in quick succession. The squirting of these drops is not noted in the very young, and only occasionally in specimens not yet full grown. It seems rather to be a habit of the adult. The imagos dodge to the opposite side of the stem when approached from one side and continue to do so just as the young. Though found feeding mostly on the central stem of the cotton plant, the females leave these parts and locate among the younger portions when they deposit their eggs. July 15 Mr. Banks dissected a female and found nineteen eggs, including those that were being formed. The female is not easily disturbed when depositing, and can even be pushed aside without inducing her to jump or fly. In one instance the form having the depositing female upon it was plucked and held in the hand, where her performances were quietly observed under cover of the hand lens.

Late in the season—that is, from about the 1st of September—the habits and actions of the adults become variable and less characteristic. There are certainly two, possibly three, broods during the season. The adults begin making their appearance in numbers from about June 1. By the middle and latter part of June numerous young can be found. The second brood begins depositing about the latter part of July. After the first days in August the adults are not so abundant until the young begin maturing again. The male adults are easily at-

tracted to lights, while the female is rarely caught in this way. Of twenty-two specimens trapped twenty were males and two females. At a lamp experiment July 19 nine specimens were captured, all males. Mr. Banks often collected adults at random, and without regard to sex, from cotton plants during the day. Eight specimens were taken on one trip, four males and four females. July 15 fifteen were captured, fourteen being females and one male. A third capture was found to contain six females and two females. This shows that females were plentiful in cotton fields at the time the lamp experiment had been made, but were not attracted. The damage to cotton by this species is due in great measure to the immature forms of the insect.

It appears that during July and August cotton fields surrounded by poplar growths along the bayous suffer the greatest attack. This is to be expected, since during June the insect lives mostly upon these trees, the young growth of which becomes too hard and tough later in the season. As has been stated, it is most numerous along river bottoms and bayous. Away from these regions this species is not at all common in cotton fields. In the upland regions of Texas, where continuous observations for one week in August were made, not a single specimen was found upon cotton. Mr. Banks, who took an extensive trip through central and southwestern Texas during July, reports the rare occurrence of this insect in those regions. Young poplar is probably their choice for food and egg deposition, but they are often found upon various kinds of weeds and miscellaneous plants. This being the case, the question of a remedy becomes a difficult one. The only recourse which seems at all practical is to control the number of young poplar trees along the bayous, keeping them at a minimum so as to obtain the maximum number of insects upon them. Then about the middle or latter part of June give them a thorough application of a strong solution of kerosene emulsion. This would kill many of the adults and most of the young, which are abundant upon them at this time.

Another nearly related species, *Proconia undata*, mostly found upon willow, is occasionally noted upon cotton. Whether its injury is similar to that of the Homalodisca has not been positively determined, but the facts already noted for the latter indicate that it may be.

REMEDIES FOR THE BOLL WORM.

LIGHTS FOR ATTRACTING THE MOTH.

The experiments presented in Bulletin 24 (pp. 33–38) proved conclusively that the ordinary lamps used by farmers and the methods of using them were inefficient. Until proven otherwise, the reasons assigned for such results were that the lights were not brilliant enough, together with being unprovided with extending wings as a background against which insects flying near by might strike and be trapped. A lamp was devised to meet all these requirements so that it could be ef-

ficient if the nature of the case permitted. The following is a description of the lamp: A tin can, 6 inches in diameter, holding about a half gallon of oil, was provided with a No. 2 wick burner capable of receiving and holding a large chimney. Around the tin can was fitted a movable tin band to which had been soldered four stout upright wires. To these wires were fastened sheets of tin a foot square, extending at right angles and from the top of the can. These wings, together with the 6-inch space between for the lamp, furnished a surface of 2½ feet toward any direction against which insects flying near might strike and drop into the large pan in which the lamp was placed. The lamp is not easily blown out of the pan if the precaution is taken to have the wings extend out far enough to catch the rim of the pan. Though a chimney was always used, in no instance was the light blown out when a strong breeze was prevailing. By experiment this lamp was found to emit a brilliant light, which was not hindered in its transmission by the extended wings.

Experiments were begun as early as May 13, 1891, and repeated at intervals on through the season. The results were all so uniform that only a few experiments need be reported in detail.

Experiment 2.

May 15.—Lighted at 8:30 p. m. Sweet corn in a garden. Locality, upland in edge of timber. During the afternoon of that day many recently deposited Heliothis eggs were found on the corn silks.

8:40.—Boll-worm moth flying along a row of corn next to the one in which the lamp is placed. When opposite the lamp, only 3 feet distant, it flew at right angles away from it. Lamp was on a level with the ears of corn on the plants and could be seen over the entire patch.

9:00.—Another moth flying as before came near, but flew away without showing any attraction to the light.

9:06.—One passed the lamp, turned, came near again, alighted upon the edge of the pan and sat there. In attempting to fly away it struck one of the tin wings and dropped into the pan.

No more moths being observed, the experiment was closed at 9:40. Though the moths were not abundant several females were seen depositing upon the fresh corn silks.

To convey a general idea of the nature of the various trappings aside from the primary insect desired, experiments 3, 4, and 5 have been collated and are presented in Table XIII.

TABLE XIII.—*Number and kind of insects caught.*

LEPIDOPTERA.

Experiment.	Date.	Noctuidæ.		Geometridæ.		Pyralidæ.		Tortricidæ.		Tineidæ		Total specimens.
		Species.	Specimens.	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.	
3	June 9	......	......	1	5	3 Botis ..	12 15	1	5	2 Plutella.	9 7	....
	Total	......	......	1	5	4	27	1	5	3	16	53
4	June 12......	......	......	......	......	2	7	1	4	3 Plutella.	10 15	....
	Total	......	......	......	......	2	7	1	4	4	25	36
5	June 27......	2	5	3	6	3 Botis..	3 30	1 4	4 4	5	15	......
	Total	2	5	3	6	4	33	5	8	5	15	67

COLEOPTERA.

Experiment.	Date.	Carabidæ.	Staphylinidæ.	Scarabæidæ.	Elateridæ.	Curculionidæ.	Scolytidæ.	Cerambycidæ.	Chrysomelodæ.	Coccinellidæ.	Total.
3	June 9......	30	......	Lachnosterna..15 Cyclocephala ..35	1	.....	.....	.....	7	....	88
4	June 12...	Large 8 Small 70	1.000	Pelidnota ....1 Lachnosterna..30 Cyclocephala . 40	25	10	.....	4	6	....	1,194
5	June 27...	Large 12 Small 150	800	Lachnosterna ..55 Cyclocephala ..75	50	7	5	7	9	Megilla 2	1.172

HETEROPTERA.

Experiment.	Date.	Cydnidæ.	Pentatomidæ.	Lygæidæ.	Capridæ.	Acanthiidæ.	Corisidæ.	Total.
3	June 9....	......	2	....	......	....	Corisa 60	62
4	June 12...	......	......	Melanocoryphus...18	6	Triphleps ..4	Corisa 15	43
5	June 27...	30	....	Melanocoryphus..100 Myodocha 3	......	....	Corisa ..1,000	1,133

HOMOPTERA.

Experiment.	Date.	Jassidæ.	Fulgoridæ.	Membracidæ.	Totals.
3	June 9	Aulacises......20	Ormenis ...11	....	37
4	June 12	35	17	13	65
5	June 27	Aulacises ......15 Deltocephalus..20	Ormenis ...10	....	45

TABLE XIII.—*Number and kind of insects caught*—Continued.

DIPTERA.

Experiment.	Date.	Mosquitoes.	Tipulidæ.	Mycetophilidæ.	Totals.
3	June 9	1,000	15	11	1,026
4	June 12	30	12	13	55
5	June 27	200	.....	100	300

NEUROPTERA.

Experiment.	Date.	Caddice flies.	Chrysopa.	May flies.	Totals.
3	June 9	20	.....	10	30
4	June 12	5	.....	6	11
5	June 27	7	1	.....	8

ORTHOPTERA.

Experiment.	Date.	Œcanthus.	Nemobius.	Platamodes.	Totals.
3	June 9	3	.....	.....	3
4	June 12	.....	.....	4	4
5	June 27	1	4	.....	5

Very few parasitic or beneficial Hymenoptera were trapped at any time and hence this order is omitted.

Table XIII can best be reviewed by taking up the orders *seriatim*.

Lepidoptera (*Moths*).—The only species of any considerable economic importance in the South is the Cabbage Plutella (*Plutella cruciferarum*). Experiments 3 and 4 were both located near a gardener's cabbage field. Its significance in this connection lies in the suggestion that gardeners growing cabbages extensively and troubled with this pest might resort to lamp trapping with advantage.

Coleoptera (*Beetles*).—Some of the large and well-known predaceous beetles were captured together with hundreds of many of the smaller species. Of the beneficial ladybird family a few specimens were trapped at various intervals. But this loss of beneficial insects is in part counterbalanced by the capture of several injurious species none of which, however, except the white grub beetles, *Lachnosterna longitarsus* and *Cyclocephala immaculata* were caught in great numbers. The last two species and a species of the wireworm beetles *Monocrepidius vespertinus* were caught by hundreds and may be considered a profitable catch. Several species of injurious weevils and flea-beetles were commonly trapped though not in great numbers. Following is a selected list of some of the beneficial and injurious beetles which were quite constantly trapped during the progress of the experiments. None of these were captured in great numbers. For the determinations of the species I am indebted to Mr. E. A. Schwarz of this Division.

BENEFICIAL.

Predaceous beetles:

Loxandrus agilis.
Badister micans.
Chlænius laticollis.
Chlænius pennsylvanicus.
Cratacanthus dubius.
Stenolophus dissimilis.
Bradycellus nigriceps.
Megilla maculata.
Hippodamia convergens.
Coccinella 9-punctata.
Coccinella oculata.
Mysia pullata.
Exochomus marginipennis.
Scymnus cervicalis.

INJURIOUS.

Flea-beetles:

Systena elongata.
Epitrix fuscula.
Chætocnema pulicaria.
Haltica ignita.
Phyllotreta bipustulata.

Wire-worm beetles:

Glyphonyx inquinatus.
Monocrepidius vespertinus.
Monocrepidius lividus.

Miscellaneous:

Lachnosterna longitarsus.
Cyclocephala immaculata.
Calandra oryzæ.
Typophorus canellus.
Lina scripta.
Diabrotica 12-punctata.
Balaninus caryæ.
Myochrous denticollis.
Colaspis flavida.

Heteroptera (*True Bugs*).—Only one species of known beneficial importance is noted. It is the small *Triphleps insidiosus* which punctures boll-worm eggs. In other experiments not tabulated an occasional soldier-bug was caught usually *Podisus spinosus.* In some of the experiments an insect (*Calacoris rapidus*) which contributes much to what is popularly termed "sharpshooter" damage was trapped in small numbers. A probably injurious cotton insect which the planters often mistook for the genuine Cotton Stainer (*Dysdercus suturellus*) is *Melanocoryphus bicrucis.* This insect was trapped by hundreds but subsequent study proved that fully 90 per cent were males.

Homoptera (*Leaf-hoppers, etc.*).—*Homalodisca coagulata* was caught in great abundance. Subsequent study showed that about 90 per cent were males.

In the three orders, Diptera, Neuroptera, and Orthoptera, nothing worthy of consideration was captured except a few specimens of the beneficial lace-wing flies.

Experiment 6.

Arlington, Tex., August 27.—Lighted at 7 p. m. and placed between rows of cowpeas adjoining a cotton field. The rows of cowpeas were 6 to 8 feet apart and had many Boll Worm moths flying about them feeding. The weather was warm and pleasant, the night very dark. Being placed between the rows, a distance of only about 4 feet remained from which to attract the passing moths. For an hour the moths kept flying up and down the rows on either side of the lamp, fed freely, deposited eggs, and paid no attention whatever to the light. A volunteer pea vine was near the center of the row having a few branches extending well up projecting over the edge of the pan within 10 inches of the flaring light. Some fresh blossoms upon them proved attractive, and a few adventurous females visited them, sipped of

their sweets for a time by lamplight and then flew away to continue their usual vocation. This act of defiance sent consternation to the hearts of some 15 or 20 planters who had been invited to attend the experiment and who during the day had insisted that if properly conducted, lights were effective agencies. All admitted that the test had been made under the most auspicious circumstances and yielded their former position with commendable grace and sincerity. Their attention was further called to a number of parasitic Hymenoptera which had been caught, some beneficial and predaceous beetles, soldier bugs, lace-wing flies, and many other species of little known economic importance such as have heretofore been given in detail and need not be repeated.

To summarize briefly, it must be concluded that the use of lights for attracting and trapping the Boll Worm moth is entirely useless. The character and habits of the other insects caught, as shown by Table XIII and its discussion, are found to be pretty evenly divided between those which are beneficial and those considered injurious. Most of the insects noted as injurious are not of special economic importance throughout the cotton region, and hence their consideration in this connection may be justly omitted. The use of lights, so far as the cotton planter is concerned, results only in the destruction of beneficial insects and is, therefore, an absolute disadvantage. Such being the case money expended in this practice is an entire loss. As a protective agency lights are a failure and should be unhesitatingly discouraged and condemned.

POISONED SWEETS.

Much has been claimed for this method of destroying the moths and a number of experiments were made to test the value and importance of the remedy. The various mixtures were applied with a Woodason liquid sprayer upon rows of cowpeas which had made a rank growth and were blooming profusely. They were freely visited by Heliothis from about 4 p. m. until 8 or 9 at night. All conditions for the experiments were favorable and furnished a good test of the poisons. The experiments were made upon Mr. C. F. Mercer's farm at Arlington, Tex., where Dr. L. C. Page, of that city, also rendered valuable assistance. By direction Dr. Page prepared saturated aqueous solutions of the poisons, and mixtures of desirable strengths with vinegar or beer were made subsequently.

Experiment 1.

August 27 (4:15).—Beer, 8 ounces; saturated cold-water solution of arsenic, 4 ounces.

August 28 (3 p. m.).—Leaves, blossoms, or young pods slightly or uncertainly injured.

Experiment 2.

August 27 (4:25).—Beer, 4 ounces, with 4 ounces of the same poison solution used in experiment 1.

August 28 (p. m.).—Foliage, blossoms, and very young pods badly scorched.

Experiment 3.

August 27 (4:35).—Vinegar, 4 ounces; 3 ounces saturated arsenic solution.

August 28 (p.m.).—Foliage, blossoms, and an occasional young pod badly scorched.

August 27.—Dr. Page was directed to prepare the following solutions:

(1) Saturated cold-water solution of commercial arsenic.

(2) 1 ounce corrosive sublimate to 1 pint cold water.

(3) 1 ounce potassium cyanide to 1 pint cold water.

Samples of each solution were kept, taken to Shreveport, and tested. They had been perfectly prepared, and the poisons were therefore actually in solution at the time of application.

The following two mixtures were prepared and used to dilute the poisoned solutions in experiments 4 to 6, inclusive:

(1) 3 pints beer to 1 pint molasses.

(2) 3 pints vinegar to 1 pint molasses.

Upon leaving Arlington, on the night of August 28, Mr. C. F. Mercer, of that city, was requested to make notes upon the damage done to the foliage by the several solutions in experiments 4 to 6, inclusive. These notes were submitted by him in a letter September 1, and the facts contained are included with their respective experiments.

Experiment 4.

August 28 (4:15).—Beer, 8 ounces; cold-water solution commercial arsenic, 4 ounces.

August 29.—Foliage scorched.

Experiment 5.

August 28 (4:45).—Beer, 4 ounces to 2 ounces potassium cyanide solution.

August 29.—Foliage shows no signs of damage.

August 30—No damage to pea vines indicated yet.

Experiment 6.

August 28 (4:55).—Beer, 4 ounces to 2 ounces corrosive sublimate solution.

August 29.—Foliage wilting.

August 30.—Dead and badly damaged.

Notes taken during the progress of the experiments show that recently issued females or those just beginning to deposit do, in fact must, meet with the poisoned liquid on the vines. Soon the moths began to alight upon the leaves or pea pods and sip of the drops of sweets to the practical neglect of the blossoms. After sipping the moths became somewhat uncertain in their flight and soon flew away and hid. It was evident to anyone familiar with their flight that the moths were affected and it was only a question of a short time when death would occur. In fact the day following the first three experiments dead moths could be found here and there when the pea vines were raised from the ground. The specimens were not old or worn-out individuals and their death was evidently attributable to the poisoned liquid which they had sipped from the vines the evening before.

The practicability of this remedy is somewhat lessened by the fact that the poisoned mixture dries rather quickly. To attain the best results it must be applied each day for a time during the egg-laying

period. This objection is valid only to a certain extent as will be noted later. The remedy is certain to be effective if properly managed. Where Boll Worm ravages are very great the additional expense and application upon a minimum area of trap-planted peas becomes proportionately a matter of secondary consideration. The crop which can be most easily and successfully managed for this purpose is that of cowpeas planted in rows 6 or 8 feet apart as a trap bordering the cotton field. They should be planted late so as not to reach the height of their blooming period before the destructive August brood of moths appears. The area should be the minimum and will depend largely upon the size of the cotton field to be protected. The blooming pea vines attract the issuing moths for feeding purposes provided the cotton be early enough to have passed its attractive blooming period. It becomes important, therefore, that the cotton be as early as possible.

As will be seen from the experiments, the difficulty arises that even moderately weak solutions of the poisons scorch the pea vines if the weather be hot and sunshiny. This scorching at once brings to an abrupt end the utility of these plants as a trap crop. This result can be obviated by making the applications as weak as is advisable to insure death to the moths and then only applying it to portions of a row upon any one evening. This leaves unsprayed healthy portions for a series of evenings to follow. Applications should be made to only a portion of each row at any given time, since observation has shown that a moth once starting in a certain row, if undisturbed, is inclined to follow it up or down for some distance. The chances of poisoning are, therefore, greater than were only certain of the rows sprayed and others not at all. In experiments 1 and 4 the same strength of the arsenical solutions was used. In the former the foliage was but slightly injured, in the latter, badly scorched. This is due to the arsenic for experiment 1 having been placed in cold water for about six hours before using, while in experiment 4 it was in cold water for twenty-four hours previous. Hence a greater per cent of arsenic had been dissolved in the latter. A poisoned mixture of arsenic prepared as in experiment 1 and applied while fresh in the proportion of 12 parts of the vinegar solution to 4 of the poisoned liquid will be efficient and yet not injure the vines. From experiment 6 it will be noted that the corrosive sublimate mixture of the same strength as those of experiments 1 and 4 was less immediate in its effects. If the dilutions were carried to the same extent as just advised for the arsenic it could doubtless be used with safety and good results. The experiment with a preparation of potassium cyanide, designated as No. 5, shows that the solution did no appreciable injury to the plants. Since it is a swift poison for insects, its use is undoubtedly effective. There could be no hesitation in concluding from the experiments that preference should be given to the cyanide preparation and its use in the proportion given in the trial recommended were it not for the fact that it was lately determined that there was a

question as to the quality of the substance used. The test of the preparation at Shreveport after the experiments had been made proved beyond question that some cyanide was in solution, but no qualitative test could be made to determine the probable quality of the article used.

There seems to be little, if any choice in the use of beer or vinegar with the molasses. Vinegar and molasses are probably more easily obtainable in the country districts, and hence are the cheapest. Fruit vinegar should be used, and a mixture of 4 parts to 1 of molasses is quite as effective as the ones used in the experiments.

For the application a fine spray is not necessary, as it is preferable that the liquid should be formed in large drops on the plants. Any of the larger spraying machines in use provided with a coarse nozzle can be used for the purpose.

Plates of the poisoned liquids were left standing upon short pedestals among the pea vines, but the moths failed entirely to visit them. Stakes which had been set among the vines were sprayed to excess, but formed no attraction. In fact, anyone who has closely observed the feeding habits of the moth can have no hope for the efficiency of any remedy except an actual application upon the food plants themselves. The usual methods of utilizing poisoned sweets against this pest are evidently useless and involve expenditures of time and money which are practically an entire loss. This conclusion is based upon the behavior of the moths toward the sweets during the egg-laying period. That time over, many individuals may be caught, but then their capture has no real economic significance.

Some advise cutting into halves numbers of ripened melons in patches adjoining cotton fields and saturating the cut surface with poisoned liquids such as have been mentioned. While at Arlington, Tex., a melon patch was found between rows of pea vines and a large cotton field. During the day it was found that where melons had been broken open and left lying during a hot day, Boll Worm moths visited them in the afternoon from about 3 o'clock. The moths unquestionably fed upon the exudations; but the practice is objectionable, since during the day it had been noted that scores of the preying wasps constantly flying about cotton fields, honey bees, and some miscellaneous beneficial insects made visits to the broken melons. All of these would necessarily be poisoned and would be a direct loss. To a certain extent the same objection can be maintained against liquids applied to cowpeas. On these plants, however, the poisoned sweet is not applied until after the heat of the day, when beneficial insects are flying about less plentifully. Furthermore, the application dries the next day as soon as the dew of the night evaporates, which greatly lessens the danger of destroying desirable insects. The drying of the poisoned application is, therefore, in one sense an advantage, as it partially counterbalances the loss in efficacy of the application.

EXPERIMENTS WITH PYRETHRUM.

Simple aqueous decoctions, as reported in Bulletin 24 (pp. 39–44), having proven a signal failure, it was thought advisable to experiment with some of the oils as agents for drawing out the insecticidal element. Headlight oil was selected, for the reason that the quality obtained from country dealers is much more constant and reliable and hence better for a series of experiments. Comparative tests of the power of extraction of the oil by various methods were made, as also of the oil combined in an emulsion with other than oil extracts. As a check upon the pyrethrum emulsions the simple oil emulsion was used in several experiments, in order that the effect of the oil in the combination might be known and any additional advantage of the second factor rendered capable of more definite determination.

SIMPLE EMULSION.

Method of preparation.—Oil 2 parts, water 1 part, and enough soap to emulsify well. Water heated and oil added while the water boiled. Churned until the mixture thickened. Prepared October 8, and is yet in perfect condition November 10. Used in experiments 1, 2, 3, and 4.

As Boll Worms were scarce, the larvæ of the Cotton Worm (*Aletia xylina*) were used in all pyrethrum experiments.

Experiment 1.

October 10 (12:35).—A 4 per cent water dilution was made and sprayed upon larvæ on cotton plants in the field. The larvæ, seventeen in number, were taken from the sprayed plants and placed upon fresh unsprayed leaves in a box, later being placed upon fresh food in breeding cages. This method was followed in all subsequent experiments. The sprayed branches in the field were always appropriately marked, in order that the effect of the emulsions upon the foliage might be noted at any time.

Date.	Living.	Dead.
October 12	1 pupating	2 half grown.
	10 grown	
	4 half grown	
Total	15	2

Experiment 2.

October 10 (12:30).—A 6 per cent dilution was sprayed upon 32 larvæ. At 5 p. m. it was noticeable that the younger worms were somewhat affected, but the larger ones showed no uneasiness.

Date.	Living.	Dead.
October 12	4 grown	2 half grown.
	12 half grown	10 very young.
	4 very young	
Total	20	12

The living larvæ less active than those in experiment 1. The foliage in experiments 1 and 2 was examined October 12 and November 23 and found uninjured. The emulsion did not seem to render the foliage distasteful, for young larvæ were subsequently found feeding upon it with a relish.

Experiment 3.

October 24 (11:15).—A 13 per cent dilution sprayed upon 12 larvæ; all nearly grown. At 4:43 1 seems slightly affected, others active.

October 26.—All active and have fed freely; two have webbed.

October 29.—Two larvæ feeding vigorously; 1 webbed and 3 pupated.

October 31.—Webbed larvæ all pupated; 1 not perfectly formed.

November 10.—Five imagos have issued. The imperfect pupa is dead, as also 4 others, which do not seem to have been normally formed, due probably to the effect of the emulsion by inducing premature pupation. Foliage slightly injured.

Experiment 4.

October 30 (4:40).—A 19 per cent dilution used upon 10 larvæ.

October 31 (9:30 a. m.).—Three larvæ badly affected; rest active and feeding.

November 2.—Six are badly affected and will probably die; others feeding.

November 3.—Six are dead, 2 pupated normally, and 2 are attempting to do so.

November 4.—Last two have pupated, but only about half the normal size.

November 17.—Two pupæ are dead; one imago has issued.

December 16.—Remaining pupa produced an imago.

Foliage examined November 10 and found badly scorched.

Pyrethrum Emulsions.

COLD-WATER DECOCTIONS.

Method of preparing first Emulsion.—To one pint of cold water one-fourth ounce of pyrethrum was added, well mixed and left to stand over night in a sealed Mason jar at a temperature of 66° F. This was done at 4:30, October 6. Filtered on the morning of October 7. Of the resulting filtrate one part was emulsified with two of headlight oil and soap as before and left to stand in a sealed Mason jar. This is the emulsion used in experiments 5 and 6. It is worthy of note that on October 10 the simple water decoction which was perfectly clear when filtered had undergone some chemical change—fermentation probably. It became very turbid, offensive in smell, and evidently unfit for further use. On the other hand, the emulsion was still perfect a month later.

Experiment 5.

October 10 (1:35).—Four per cent dilution. Number of larvæ sprayed, 16.

October 12.—Both large and small active and feeding. One, about half grown, dead.

Experiment 6.

October 10 (1:20).—Seven per cent dilution. Number of larvæ, 21.

Date.	Living.	Dead.
October 12	1 pupa 2 grown 9 half grown	9 half grown.
Total	12	9

Foliage in experiments 5 and 6 uninjured.

The second emulsion was prepared as the first experiment, except that the proportions were 3 ounces of pyrethrum to 1½ pints rain water. This is the emulsion used in experiments 7, 8, and 9.

Experiment 7.

October 10 (*12 m.*).—Four per cent dilution. Number of larvae, 16.

Date.	Living.	Dead.
October 12	1 grown 4 half grown 5 very young	4 half grown. 2 very young.
Total	10	6

Experiment 8.

October 10 (*11:40 a. m.*).—Six and one-half per cent dilution. Number of larvæ, 19.

Date.	Living.	Dead.
October 12	6 grown 6 half grown	5 half grown 2 very young
Total	12	7

Experiment 9.

October 24 (*11:55 a. m.*)—Thirteen per cent dilution. Number of larvæ, 10. At 4:37 p. m. 1 larva had webbed, but was badly affected. The other 9 were active and feeding.

October 26.—One pupa, 8 active and feeding; 1 dead, half grown.

October 27.—One more webbed.

October 29.—One more pupa, 4 webbed, and 3 feeding.

November 20.—All but one pupa which was imperfectly formed, have produced imagos. The imperfect pupa is dead. The foliage in experiments 7, 8, and 9 was uninjured.

HOT-WATER DECOCTION.

Three ounces of pyrethrum were added to 1½ pints rain water, placed in a sealed Mason jar, and boiled for one hour. Filtered and emulsified a portion of the filtrate with headlight oil. This is the emulsion used in experiments 10, 11, and 12.

Experiment 10.

October 10 (*11 : 25*).—Four per cent dilution. Number of larvæ, 19.

Date.	Living.	Dead.
October 12	4 grown 9 half grown 2 very young	2 half grown 2 very young
Total	15	4

Experiment 11.

October 10 (11:05).—Six per cent dilution. Number of larvæ, 40.

Date.	Living.	Dead.
October 12	1 webbing	6 half grown.
	7 grown	3 very young.
	22 half grown	
	1 very young	
Total	31	9

Experiment 12.

October 24 (12:05 p. m.).—Thirteen per cent dilution. Number of larvæ, 9. At 4:53 larvæ still active and apparently unaffected.

October 26.—Have fed freely; 3 webbed.

October 29.—One feeding; 5 webbed; 3 pupæ.

November 13.—Two pupated imperfectly and died; others have issued.

COLD-OIL DECOCTION.

One and one-half ounces pyrethrum added to one-half pint headlight oil placed in a sealed Mason jar and left over night at a temperature of 68° F. Filtered the next morning and emulsified the filtrate with half as much rain water. This emulsion was used in experiments 13, 14, and 15.

Experiment 13.

October 10 (1:05 p.m.).—Four per cent solution.

October 12.—Three nearly grown larvæ lively; 5 dead, all about half grown. This breeding cage, as also the one of experiment 14, was found to have cracks in, which had been unnoticed, and many of the larvæ escaped.

Experiment 14.

October 10 (12:55).—Seven per cent dilution. Late in the evening the larvæ appeared somewhat uneasy.

October 12.—Two half-grown ones may live; 11 half-grown ones are dead.

Experiment 15.

October 24 (11:25).—Thirteen per cent solution. Number of larvæ, 10. At 4:25, 4 half-grown larvæ are unable to crawl; 2, about a third grown, in the same condition; 4 nearly grown ones can travel about, though their actions are not perfectly normal.

October 26.—Two trying to web up; 1 larva feeding, and 7 dead. Of the dead, 5 are half grown, the other 2 younger.

October 29.—A Boll Worm in the cage attacked and devoured one of the webbed-up larvæ; the second one pupated, and the third died in the attempt.

November 17.—Pupa has produced an imago.

In experiments 13 and 14 the foliage remained unimpaired, but in experiment 15 it was slightly scorched.

HOT-OIL DECOCTION.

One and one-half ounces pyrethrum added to 1 pint headlight oil, and at 10:45 a. m. the jar was placed in a water bath to heat to a temperature a few degrees short of the point of explosion, namely 170° F. At 11 a. m. a temperature of 160° F. was

reached and maintained for an hour. Filtered while hot into another Mason jar, sealed and set aside to cool. After cooling the filtrate was emulsified as before. This emulsion was used in experiments 16, 17, and 18.

Experiment 16.

October 24 (*11:45*).—Four and one-half per cent solution. Larvæ, 9 in number. At 5:10 7 larvæ, half grown or over, though quite active, appear slighly affected; 2 are badly affected.

October 26.—Three large ones alive and feeding; another is alive, but not active; 1 has webbed up, and 4 half-grown ones are dead.

October 29.—One live pupa; 2 webbed; 2 dead, including the one which had webbed October 26.

October 31.—Two more pupæ, 1 well formed, the other not.

November 29.—Two imagos issued; the imperfect pupa dead.

Experiment 17.

October 24 (*11:35*).—Thirteen per cent solution. At 4:48, 3 nearly grown hardly able to crawl. All are evidently uncomfortable.

October 26.—All but one are dead. This one is making a poor attempt at pupating. None fed any before dying.

October 29.—Succeeded in pupating, and is still alive. Later, pupa dead.

Experiment 18.

October 30 (*4:15*).—Twenty-one per cent solution. Number of larvæ, 10; almost grown. At 4:30 all are off the fresh, unsprayed branches and tumbling about in the cage. All but one are in convulsions; the one exception is not active—in fact, can not crawl.

October 31 (*9:30 a. m*).—Every effort to place the larvæ upon the branches proves useless today, as it did last evening. The larvæ have not the slightest control of themselves.

November 2.—All are dead. In experiment 16 the foliage was unharmed; in 17 slightly scalded, and in 18 badly scorched.

SIMPLE COLD-WATER DECOCTION.

Three ounces pyrethrum were added to 1½ pints rain water and left to soak over night at 68° F. Filtered the next morning and the filtrate kept in sealed Mason jar. Decoction prepared October 7 to 8. Used in experiments 19, 20, and 21.

Experiment 19.

October 8 (*4:55 p. m*).—Full strength decoction sprayed upon larvæ of all sizes on a branch of cotton in the field. The smaller ones began dropping off almost immediately. The larger ones showed no desire other than to get away from their moistened quarters.

October 9.—Many worms feeding, some nearly grown, others very young, and but recently hatched, none appearing much affected; 16 larvæ, all less than half grown, dead.

October 10.—Can now tell which ones will survive. Three almost grown, 5 half grown, and 7 very young. The dead numbered 22, all very young and recently hatched.

In experiment 20 only half strength of the decoction was used. This gave even less effective results than the full strength, and need not be presented.

The filtrate of the fresh decoction on October 8 was clear, and had rather a pleasant smell. Subsequently, though kept in a sealed Mason jar, it became decidedly

turbid, formed a precipitate, and has a sour or vinegar-like smell. The pyrethrum smell is but faintly recognizable.

Experiment 21 was made for the purpose of determining any difference in the effect of the changed or fermented decoction and the fresh filtrate.

Experiment 21.

October 24 (12:25).—Full strength applied. At 5 p. m. all the larvæ, 8 in number, lively.

October 26.—All well and active. 2 having webbed.

October 29.—One feeding vigorously, 4 webbed, and 3 pupæ. Evidently no results, and experiment closed.

SIMPLE HOT-WATER DECOCTION.

Three ounces pyrethrum to 1½ pints rain water, boiled for one hour in a sealed Mason jar. After boiling, filtered and kept filtrate in sealed Mason jar. This decoction was prepared October 8, and used in experiments 22, 23, and 24.

Experiment 22.

October 8 (4:20).—Full strength sprayed upon 49 larvæ. The very young began tumbling off in a few minutes. By 5 p. m. many of the newly hatched larvæ were evidently dying.

Date.	Living.	Dead.
Oct. 10	3 grown 10 half grown 5 very young	7 half grown. 24 very young.
Total	18	31

Experiment 23 was a half strength of the same decoction and, as no special results were obtained, can be omitted.

Though this decoction had been boiled, the filtrate subsequently became turbid and formed a whitish precipitate. Practically in the same condition as the decoction used in experiment 21.

Experiment 24.

October 24 (12:15).—Full strength of the fermented decoction sprayed upon the larvæ. Their behavior in all important respects was the same as of those in experiment 21.

Experiment 25.

October 10 (1:40).—A number of worms were simply sprayed with cold water as a check upon the effect which a forcible wet spray would have upon the very young and half-grown larvæ. Almost immediately occurred the usual dropping off of the very young larvæ and the seeking of dry quarters noted in the other experiments with the aqueous decoctions.

October 12.—All but one half-grown one are quite active and feeding.

Date.	Living.	Dead.
Oct. 19	5 pupæ 1 half young	3 half grown. 7 very young.
Total	6	10

Experiment 26.

As a check on the deaths due to picking and transferring the larvæ to breeding cages, as also upon feeding in confinement, a number of larvæ were picked October 10, as in the other experiments, transferred, and in all respects cared for as the others had been.

Date.	Living.	Dead.
Oct. 12	3 grown 5 half grown	2 half grown. 4 very young.
Total	8	6

The facts contained in the several experiments are tabulated for convenience in Tables XIV and XV.

TABLE XIV.—*Results of experiments with various insecticides.*

Insecticide.	Strength.	Experiment.	Number of larvæ.	Survived. Grown.	Survived. Half grown.	Survived. Very young.	Dead. Pupæ.	Dead. Grown.	Dead. Half grown.	Dead. Very young.	Totals. Living.	Totals. Dead.
Oil emulsion	4 per cent	1	17	11	4	....	....	....	2	....	15	2
	6 per cent	2	32	4	12	4	....	....	2	10	20	12
	13 per cent	3	12	7	....	....	5	....	....	....	7	5
	19½ per cent	4	10	2	....	....	2	6	....	....	2	8
Pyrethrum emulsion, cold-water decoction.	4 per cent	5	16	7	8	....	....	....	1	....	15	1
	7 per cent	6	21	3	9	....	....	....	9	....	12	9
	4 per cent	7	16	1	4	5	....	....	4	2	10	6
	6½ per cent	8	19	6	6	....	....	....	5	2	12	7
	13 per cent	9	10	8	....	....	1	....	1	....	8	2
Pyrethrum emulsion, hot-water decoction.	4 per cent	10	19	4	9	2	....	....	4	....	15	4
	6 per cent	11	40	8	22	1	....	....	6	3	31	9
	13 per cent	12	9	7	....	....	2	....	....	....	7	2
Pyrethrum emulsion, cold-oil extract.	4 per cent	13	(*)	3	....	....	....	....	5	....	....	....
	7 per cent	14	(*)	....	2	....	....	....	8	3	....	....
	13 per cent	15	10	2	....	....	1	....	5	2	2	8
Pyrethrum emulsion, hot-oil extract	4½ per cent	16	9	2	....	....	1	2	3	1	2	7
	13 per cent	17	6	....	....	....	1	3	2	....	....	6
	21 per cent	18	10	....	....	....	....	7	3	....	....	10
Cold-water decoction of pyrethrum	Full	19	37	3	5	7	....	....	8	14	15	22
	Full	21	8	† 8	....	....	....	....	....	....	8	....
Hot-water decoction of pyrethrum.	Full	22	49	3	10	5	....	....	7	24	18	31
	Full	24	(*)	....	....	....	....	....	....	....	....	....
Check experiments	Cold water	25	16	5	1	....	....	....	3	7	6	10
	Picked larvæ	26	14	3	5	....	....	....	2	4	8	6

* Not counted; see record of experiments in the text.
† See record of experiment in the text.

TABLE XV.—*Experiments with different strengths of pyrethrum.*

Strength.	Experiment.	Number of larvæ.	Survived.			Dead.				Totals.	
			Grown.	Half grown.	Very young.	Pupæ.	Grown.	Half grown.	Very young.	Living.	Dead.
4 per cent	1	17	11	4	....	....	....	2	......	15	2
4 per cent	5	16	7	8	....	....	....	1	......	15	1
4 per cent	7	16	1	4	5	....	....	4	2	10	6
4 per cent	10	19	4	9	2	....	....	4	......	15	4
4 per cent	13	(*)	3	....	....	....	....	5	......	......	......
4½ per cent	16	9	2	....	....	1	2	3	1	2	7
Totals	....	77	25	25	7	1	2	14	3	57	20
6 per cent	2	32	4	12	4	....	....	2	10	20	12
6 per cent	11	40	8	22	1	....	....	6	3	31	9
6½ per cent	8	19	6	6	....	....	....	5	2	12	7
7 per cent	6	21	3	9	....	....	....	9	......	12	9
7 per cent	14	(*)	....	2	....	....	....	8	3	......	......
Totals	....	112	21	49	5	....	....	22	15	75	37
13 per cent	3	12	7	....	....	5	....	....	......	7	5
13 per cent	9	10	8	....	....	1	....	1	......	8	2
13 per cent	12	9	7	....	....	2	....	....	......	7	2
13 per cent	15	10	2	....	....	1	....	5	2	2	8
13 per cent	17	6	....	....	....	1	3	2	......	......	6
Totals	....	47	24	....	....	10	3	8	2	24	23
19½ per cent	4	10	2	....	....	2	6	....	......	2	8
21 per cent	18	10	....	....	....	....	7	3	......	......	10
Totals	....	20	2	....	....	2	13	3	......	2	18

* Not counted; see record of experiment in text. Larvæ of this experiment not included in the totals.

SUMMARY OF THE EXPERIMENTS.

When studying the above tabulated results it must be constantly borne in mind that the larvæ of Boll and Cotton Worms resist the ordinary liquid insecticides of such strengths as are usually effective against other insects, such as bugs or leaf-hoppers. Another important fact to notice is that whatever effect was obtained from a certain solution or decoction is to be attributed solely to it, since the larvæ were transferred to cages in the shade away from the direct sunlight. The assistance of direct sunlight in producing scorching effects with the oil emulsions is entirely eliminated, and explains why the larvæ seem to have withstood unusually strong solutions. For this reason the results obtained, though possibly less striking, have greater significance as to the real value as insecticides of the combinations made.

The foliage in the field was injured less than might be expected with such strong solutions on account of the cool, dewy nights and moderate temperatures during the day at the time when the experiments were made. It is needless to dwell further upon these conditions, except to state that the same strengths of emulsions if applied during the heat of day in midsummer would affect both larvæ and foliage proportionately in a more decided and vigorous manner. This, however, has no direct bearing upon the primary purpose of the experiments, which was to

discover some easy and practical method of obtaining an extract of pyrethrum, which really added some insecticidal property to the remedy with which it was combined. For this reason in the oil experiments it was manifestly necessary to eliminate the factor of direct sunlight.

In order, however, that this series might be complete in itself a few experiments with cold and hot water decoctions of pyrethrum were repeated. Their results are presented in experiments 19 to 24, inclusive. Comparing these with check experiments 25 and 26 it becomes evident that neither cold nor hot aqueous extracts have any value as remedies against the more mature larvæ, and have but slight utility even against the younger worms. This agrees with what has already been reported in Bulletin 24, p. 43. Results to be of great value in making comparative tests of the remedies should on the whole be obtained by experimenting with older individuals. In the experiments not already discussed considerable selection was exercised in this respect.

The aqueous decoctions of the powder having proven of no value against the more mature larvæ, we should expect to find that the results of these experiments with the oil emulsions combined with these aqueous decoctions would not differ materially from those of the simple oil emulsions of equal strengths. Inspecting Table XVI it is found that experiments 1 to 4, inclusive, were with simple oil emulsions; those of experiments 5 to 12, inclusive, were the same combined with cold and hot decoctions of pyrethrum. In Table XV equal strengths have been tabulated. Noting in this table the experiments just referred to, no appreciable difference is found in comparing experiments 1 with 5, 2 with 6, 8, or 11, 3 with 9 or 12. For a series of independent trials the variation in results is but slight, and the combinations in question seem, therefore, to have no special advantage over the simple emulsion.

Studying next the cold oil-extract emulsions by comparing experiment 15 with 3, 9, or 12, which latter are simple oil emulsions of equal strengths, some difference favorable to the oil extract is shown. The difference can not be fully discussed, since, by an accident, the records of two of the experiments are not complete. It was observed, however, that the activity of the larvæ treated with the oil-extract emulsion was more excited and pronounced than that of those treated with the simple emulsions.

Coming now to the hot oil-extract emulsions, we find some remarkable results. For example, in experiment 16, where a 4½ per cent dilution of this emulsion was used, it is found that grown larvæ were affected to an extent almost equal to a 13 per cent solution of the simple emulsion. Again, in experiments 15 and 17, Table XV, it is found that when 13 per cent solutions of the hot and cold oil extracts were applied to grown larvæ, results favorable to the emulsified hot oil extract followed, the latter killing every larva used in the experiment. The hot oil extract having greatly increased the efficacy of the emulsion, it is to be expected that the cold oil will add to itself, in a less degree and more

slowly, a portion of the active principle of the pyrethrum. The slight advantage of the emulsified cold oil extract over the simple emulsion as already indicated is, therefore, corroborated by the decided advantage of the emulsified hot oil-extract preparation.

The effect of pyrethrum upon larvæ is to throw them into convulsions or paralyze the muscles so that they have no power to direct their movements. None of the emulsified extracts applied to the larvæ produced such effects until we come to the emulsified cold oil applications. In these, the characteristic effects are rather uncertainly indicated in the stronger applications. With the hot oil-extract emulsion such actions were already manifested in the weaker 4½ per cent dilution, and very decidedly in the stronger applications. For example, in experiments 17 and 18, fifteen minutes after the application the full-grown larvæ had utterly lost control of themselves, and it merely became a process of dying from that time. No chance for pupation, as in some of the other experiments.

These facts show that there was really an additional insecticidal effect acquired by the hot oil decoction process, the extract of which was subsequently emulsified.

ADVANTAGES OF THE EMULSIFIED HOT-OIL EXTRACT OF PYRETHRUM.

The experiments above summarized again prove that the ordinary methods of extracting the active principle of pyrethrum are questionable, or at least unsatisfactory. The hot oil experiments show conclusively that this method does to some extent draw out the insecticidal element of the powder, and retains it in the emulsion. However, its use upon host plants which are able to resist without injury an oil emulsion application of sufficient strength to destroy the insect is more expeditious and, perhaps, more economical than the use of the pyrethrum emulsion. But plants which are injured by such an emulsion can be successfully treated with a weaker solution of the pyrethrum emulsion, not injuring the foliage, and destroying the pest as effectually. This is shown by Table XIV, where, with a 4½ per cent pyrethrum emulsion in experiment 16, we have practically the same effect upon the growing larvæ that a 13 per cent oil emulsion has in experiments 3, 9, or 12. The two latter can be regarded as purely oil emulsions, since it has been shown that the aqueous decoctions of the powder really contained no insecticidal properties.

During high temperatures and bright sunshine it is well known that more or less danger of injury to the plant is risked by the use of an oil emulsion when the strength which must be applied comes very near the maximum which the foliage will bear. This risk can be greatly lessened by using the pyrethrum emulsion, because the maximum strength which the plant will withstand need not be approached so closely. This advantage should not be interpreted as a protective effect of the pyrethrum to the foliage, but as an additional insecticidal factor making the usual quantity of oil unnecessary.

HAND-PICKING OF CORN.

In May, from the time when boll-worm injuries are first noticed in the buds of corn plants, the infested ones should be crushed in the hands so as to kill the worms found in them. To determine whether this could be successfully done, the method was tried while taking notes on the number of worms and infested plants in a field during May and June. The result is given in Table I, and shows that of a total of 26 larvæ, 23 (7 half grown and 16 very young) were crushed. It is therefore a satisfactory process. From the same table it is found that only 2.6 per cent of the plants showed injury. Hence but little time will be required to go over a large field in this manner. After an interval of two weeks, the process should be repeated. This will decrease the numbers of the later broods to such an extent that in many slightly-infested regions nothing further will be necessary, especially if infested ears of sweet corn be burned instead of simply thrown away.

TRAP-CORN EXPERIMENTS.

Experiment 1.

A portion of a plantation owned by Mr. Dan. Nicholson was kindly set aside by him for a trap-corn experiment. The field was rich Red River bottom land, bordered on the east by a large forest, but surrounded on all other sides by cotton fields. Five rows were left vacant on the outer edge of the field, then eighteen rows of cotton planted, four more rows left vacant, then eighteen of cotton, and so on. The cotton was planted at the usual time. Two rows of each of the vacant strips were planted in corn April 4. May 7 this corn averaged about 1 foot in height. No boll worms were found in the buds of the plants, though in a field of corn some 300 yards away, which had been planted at the usual time, a few were collected. This field of early planted corn was near the garden and was surrounded on two sides by fences which were thickly grown over by flowering plants and dewberry vines. As no worms were found some distance from the edge of the field, it was evident that the first brood of moths had been somewhat attracted to the adjoining blossoming plants near the hedge and in the garden, and had confined their deposition to the outer edges of the field. This becomes an important factor when considering the feasibility of resort to killing the first brood of worms in the buds of corn by crushing. This does not apply to larger areas of corn where similar attractions are not near at hand. The trap corn was not so situated, but was in the midst of a large plantation, away from such early inducements.

On July 3 a visit to the trap crop was made. It was, and probably for some days had been, silking profusely just as the second brood of moths was issuing. By July 6 the first planting had passed its prime in point of silking, though still in fit condition to receive the deposition of many eggs. At the time of the July 3 visit the following study of the number of larvæ found in the young ears was made:

Plant.	Ears.	Larvæ.
1	2	6
2	1	1
3	2	4
4	2	3
5	2	7
6	2	5
7	2	3
8	1	1
9	1	7
10	2	2
11	1	2
Total	18	41

The larvæ at this time were nearly all less than half grown, only two of the number being nearly grown. These two were found alone in the ears of plants 2 and 8. In the ear of plant 9, which contained seven larvæ, all less than half grown, two were discovered being eaten by others.

By July 25, the second planting in the remaining two vacant rows was in its prime, but by August 1 had passed its best condition. The time of its greatest attractiveness covered the period of the issuance of the third brood. This brood deposited upon the fresh silks to such an extent as to produce an extremely crowded condition, for the larvæ expected to find food upon such a limited number of ears. Many ears were examined and all presented so nearly the same condition that only a few counts were made. These were:

Plant.	Ears.	Larvæ.
1	1	10
2	2	8
3	3	15
Total	6	33

At the time of this examination, August 1, the larvæ were still all very small, probably two-thirds having never molted. In addition, the ears above noted for the larvæ seldom bore less than six to a dozen fresh eggs upon their silks, often ranging from a dozen to twenty. In the same field, in ears in which nearly-grown larvæ were found, only a few, if any, younger ones were present. This indicates that the crowded condition led the larger and stronger ones to prey upon the others, thus giving the victors more room and food.

The ears of the first planting had now hardened, and no larvæ were found in them and no fresh eggs were being deposited on their leaves and husks. Eggs were still being deposited upon the plants of the second planting. The cotton between the rows of trap corn was carefully examined during the egg-laying period without finding eggs or bored bolls, even in the rows immediately adjoining those of the trap corn.

Experiment 2.

Through the kindness of Mr. A. Curtis, of Curtis, La., a large and fertile tract of land, also in Red River bottom, was placed at my disposal for experimental purposes. The cotton was planted at the usual time, one row for every fifteen being left unplanted. This one row was planted in corn April 9. May 7 the rows of young corn were examined, but no larvæ were found in the plants. A small field of crop corn, planted earlier and joining the experimental field on one side, had a few worms in the buds of some of its plants. The second visit was made July 3, when the corn was found in splendid condition for egg-deposition. The following studies were made of infested ears:

Plant.	Ears.	Larvæ.
1	2	5
2	2	2
3	2	10
4	1	7
5	1	3
6	1	1
7	2	3
8	1	1
9	1	3
10	2	7
Total	15	42

A similar study was made of the adjoining small field of rapidly maturing crop corn, with the following results:

Plant.	Ears.	Larvæ.
1	Bored*	0
2	Bored	0
3	Bored	0
4	1	1
5	2	2
6	1	1
7	1	0
8	1	0
9	Bored	0
10	Bored	0
Total	11	4

* By bored is meant that a worm had been in the ear but had left, either for another ear or to pupate.

Inasmuch as eggs were found quite plentiful upon the trap corn and none were found upon the other, it is apparent that the moths had chosen between the two.

The number of plants and ears, such as the females would readily deposit upon, was counted. One row contained 148 plants with 267 ears. Each of the remaining rows was of the same length (about 10 or 15 rods) and contained approximately the same number of plants and ears. From the count of the number of worms in the ears of this trap corn, as above given, an average of 2.8 worms per ear is derived. Therefore the above row contained about 747.6 worms. For the eight rows of trap corn in this field, this makes 5,981 as the approximate number of worms trapped. This leaves out of consideration the unhatched eggs found in the silks at that time.

May 23 a second trap planting was made, in a field immediately to the right of the first experimental field. By July 6 it had not yet tasseled, though it was badly infested with another species which was feeding in the buds, just as the Boll Worm does.

Later, about the 1st of August, the second experimental field had silked and was well stocked with boll-worm eggs, many of which were parasitized. The larvæ were plentiful in the ears, and as nothing of further interest could be attached to the experiment, Mr. Curtis cut the corn and fed it for forage.

Experiment 3.

[Mr. J. H. Fullilove's plantation.]

Corn was planted April 13. May 7 it was still small. No Boll Worms in the young plants. Two hundred yards away was a field of corn which had been planted much earlier. In this a few young Boll Worms were found. July 3 the ears of the trap corn were badly infested with Boll Worms and many unhatched eggs were upon the silks. The conditions in general were much the same as in the preceding, and need not be repeated in detail.

Experiment 4.

[Mr. S. J. Ziegler's Plantation.]

One field was rather more upland and less favorable for a good growth of late-planted corn. The first planting of corn was April 9. April 24 the corn was from 4 to 6 inches high, but contained no Boll Worms. It tasseled and silked subsequently and the ears were badly infested.

June 29 the second row was planted. July 28 the plants were 10 to 15 inches high, and had boll-worm eggs upon the leaves. The weather had been very dry during July, and the corn made an unsatisfactory growth, few plants producing ears with large flowing silks.

In another of Mr. Ziegler's fields corn was planted May 19. July 28 this was in fine silk. By actual count the silk of a single ear was found to have twenty-five unhatched boll-worm eggs. Most of the silks had only about a dozen eggs, with from three to six larvæ in the ears.

Late in July notice was received from Mr. John Glassell, jr., a leading planter at Rush Point, La., who had read the recommendations given by the Division upon the boll-worm question, and had prepared to test the suggestion. By his invitation the plantation was visited July 25, and a complete verification of our own experiments proved to be in waiting. Mr. Glassell had planted corn at the time of the second hoeing, when the cotton was about knee-high, or, as he informed me, about May 20. At the time of the visit the third brood of moths was fairly issuing. The trap corn was in fine silk, and the record of a few of the many ears examined will suffice to indicate what they were accomplishing. One ear, 11 larvæ, 7 eggs on silks; another ear, 6 larvæ, 10 eggs on silks. The closest inspection of the cotton plants surrounding this corn failed to reveal any traces of boll-worm injury. Various fields of corn near by were examined but no boll-worm eggs were found. The fresh silking corn was nearly in the center of a number of these fields and seemed to be receiving almost the entire egg deposition of the issuing brood in that immediate locality. Mr. Glassell enthusiastically accompanied your agent during all the observations, with a view of thoroughly informing himself of the facts and enabling himself to estimate the value of this method of protecting cotton. Subsequently he continued to make close observations and reported himself as being well satisfied with the remedy. In this connection it may also be stated that much valuable corroborative evidence was obtained from Mr. S. B. Mullen, of Harrisville, Miss., who had been advised of the trap-corn experiments. He arranged several small fields to make a test of the idea, and all of his reports by letter are in entire accord with what has already been stated.

The plantations thus far considered were bottom lands. The cotton in and about trap-planted fields was practically free from boll-worm injury. This could in a measure be said of other cotton fields in the valley, because the Boll Worm did not appear in destructive numbers during the season. This in reality does not affect the facts recorded for the corn experiments, and their significance relative to the moths which did appear remains the same.

In the "hill country" of Louisiana and portions of Mississippi away from the river valleys, the Boll Worm is not noticed or feared much except during very destructive years, when it spreads from the bottom lands.

A small farm in the uplands west of Shreveport was prepared for experiment in much the same way as those in the valley. Corn was planted May 16. By June 16 it was knee-high, but no worms were found. July 9 corn was tasseling and beginning to silk, but as no moths appeared in this locality, no eggs were found. To trap the first brood requires corn in silk from about May 15 to June 1. This is too early a date to be reached by the yellow or Dent corns. In its stead a sweet corn, commonly planted in the south for table use, meets the requirements. This corn had passed silking and was in good roasting ears before the first of June. Some of the studies made upon it are exhibited in Table II, which shows how badly it was and had been attacked. At the time of the count many unhatched eggs were still to be found upon the silks. Care must be taken, however, not to estimate the abundance of the Boll Worm and the extent of its injuries from such examples. The Dent corns also make an unsatisfactory growth when planted late enough to bring silking about the first of August. In its stead the sweet corn again meets the conditions.

The plan, therefore, to be recommended to the planter for using the trap-corn method of protecting his cotton against boll-worm injury may be summed up as follows: When planting the cotton leave vacant strips

of five rows for every twenty-five of cotton to be planted in corn. At the earliest possible time plant one row of this with an early maturing sweet corn. It should not be drilled in too thickly, since only a minimum number of plants and ears is desired. During the silking period of this corn frequent careful examinations must be made as to the number of small white or brownish banded eggs, hardly larger than a pin head, found upon them. As soon as no more fresh white eggs are found each morning, the silks and ends of the ears should be cut away and fed or burned in order to destroy the young worms and the eggs. A few eggs may be on the leaves of the plants, and since no more growth is to be made, they also should be cut and taken from the field. There is no reasonable objection to this method of handling the first planting, since the natural enemies are not yet numerous and the egg parasites appear in greater numbers during the egg-laying period of the next brood. The next planting should be three rows of Dent corn, drilled in late enough to bring the silking period about the first of July or a little later. These rows catch immense numbers of eggs and larvæ, but should be left to mature in order that the natural enemies which parasitize the eggs and prey upon the larvæ may not be destroyed. Furthermore, the cannibalism previously discussed, which occurs in this corn under such crowded conditions, reduces the number of worms reaching maturity to a minimum, and these can well be allowed to escape if the natural enemies be saved thereby. To trap these escaped individuals, the fifth and last row of the vacant strips should be planted to sweet corn at a time calculated to make it reach full silk about August 1st, when the moths begin issuing again. This expedient allows the planter to save the second planting as a crop. The corn produced in this way is large enough in quantity to pay for the expense of cultivation and management and the sacrifice made in cropping the five rows with corn instead of cotton. However, it must be understood that this is immaterial so long as protection is afforded to the surrounding cotton. The last row of sweet corn should be carefully watched. If it is found that a great many eggs are parasitized, a fact which is indicated by their uniform grayish or blackish color, it may be as well to allow it to mature as before and thus save the parasites. If this condition is not found, the corn should be cut and taken from the fields as soon as it shall appear that no more eggs are being deposited.

If the first two plantings are well managed, the number of the earlier broods will be so reduced that the August brood will not be capable of inflicting great injury, and in less infested regions the third planting may even become superfluous.

It is not necessary or advisable to crop the entire plantation with corn and cotton as recommended. The end will be attained if five-acre strips of alternate corn and cotton be planted for every fifty acres of

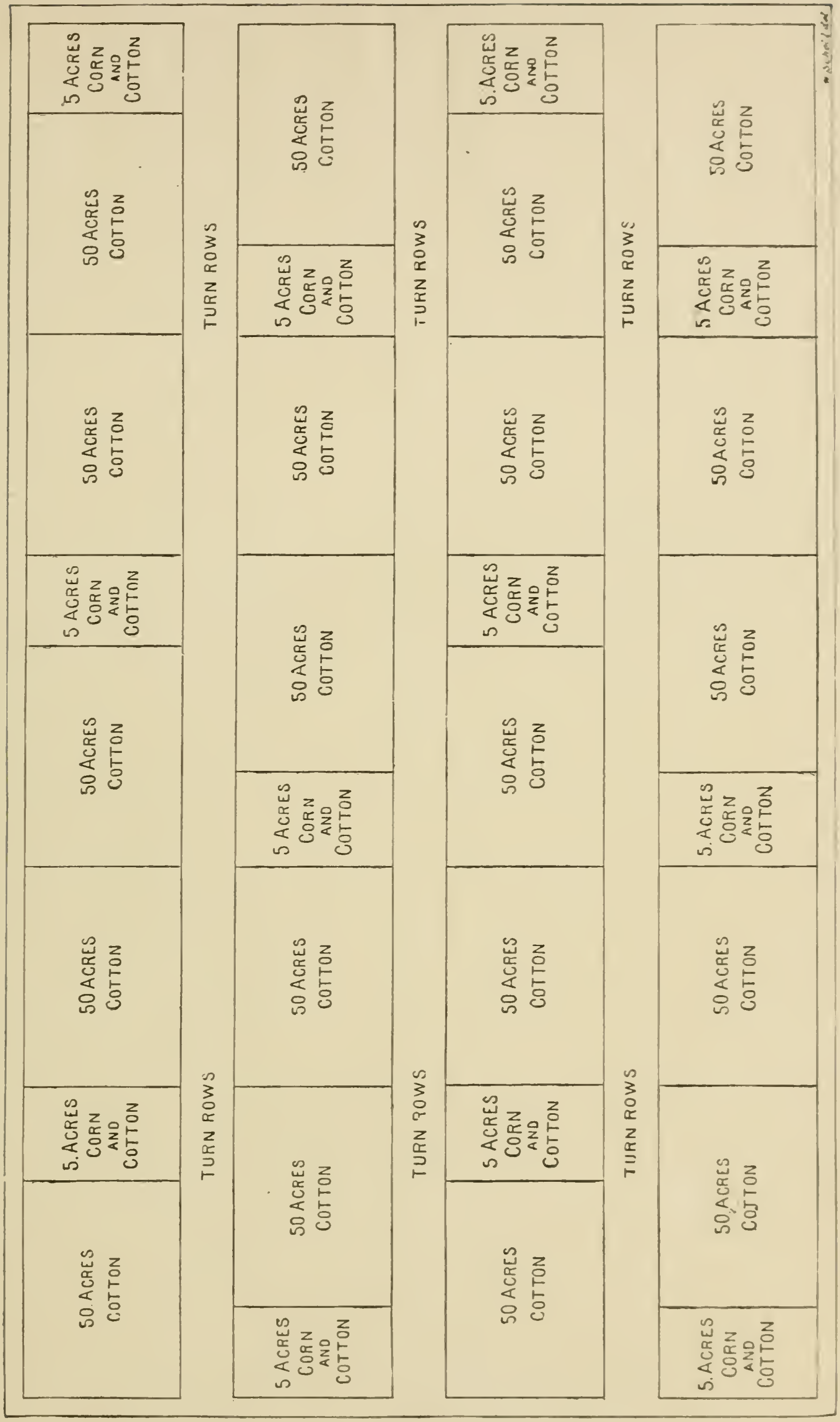


DIAGRAM OF COTTON FIELD, SHOWING LOCATION OF TRAP CORN.

cotton. For less infested regions 5 acres of trap crop for 75 or 100 acres of cotton may suffice to insure the same protection. By a judicious arrangement of the trap crop and cotton lots the five acres of the former may, in the same proportions as above given, be made to act as a protection for just twice the number of acres of cotton above designated. To illustrate this, the accompanying diagram (Plate I) for a plantation of 1,060 acres is presented, and is suggested as probably the best plan for placing the trap corn to the best advantage and insuring the greatest immunity.

On May 27, in company with Prof. Jerome McNeill, a trip was taken to Rustan and Calhoun about 60 miles east of Shreveport. This region is quite heavily wooded, mostly hilly and broken. Along the entire route, often passing beyond the Red River Valley, the crops were at least three weeks behind those of the river bottoms. A similar difference occurs in Texas. Southern Texas is about two or three weeks earlier in point of season than the northern portions. From this great extent of the cotton producing regions, and the variability of the conditions in different localities, it becomes advisable to waive all specific recommendations and depend upon the planter to determine the exact time during which the broods of moths to be feared deposit their eggs in his immediate locality and manage his trap crop accordingly. By way of emphasis and to avoid being misunderstood by farmers, it may be remarked that the time of appearance and egg deposition of the moths is the point in question, and not the worms. Should the farmer base his calculations on the latter, he will fail entirely, since the females will have issued a week or ten days previously and have laid their eggs upon some other host.

The regular crop corn can be protected to a certain extent if care is taken to plant it as early as is expedient, calculating to have it beyond its prime in silking before June 10. If rows of corn near by are planted at a time to bring silking about July 1, the protection to the corn crop will be still more complete. For this reason late planted corn which silks about July 1 is much more eaten by Boll Worms than that planted earlier.

It has already been intimated that the earliest appearances of Boll Worm injury are noticed in patches of early sweet corn in the numerous small gardens throughout the cotton country. These practically form a breeding ground for the first brood. The evident importance of hand picking and destroying the larvæ in these patches is hardly to be overestimated. In fact, it may be quite as practicable to recommend that these small patches be planted with the intention of destroying the corn as soon as an examination of the ears shall show them to be well stocked with worms and eggs. An early planting of sweet corn as a trap crop in cotton will divide the attack upon the gardener's corn intended for the market and meet this source of complaint as well.

As has been previously noted, the worst infested Boll Worm districts seem to correspond to a certain extent with those regions in which the proportional area of corn is greatest. By some this is put forth as an objection to the trap corn method. The greater acreage of corn results in a greater number of individual ears in which the worms can mature without inducing cannibalism among them. For this reason the first broods succeed in maturing a greater number of individuals which leave the corn when it matures and attack cotton. At the time, therefore, when the trap corn matures and the adults of the destructive brood begin appearing, the properly managed rows of trap corn will be in suitable condition and will attract to themselves the greater portion of the egg deposition. The objection, therefore, is not well taken, but rather, in view of the greater number of the August brood resulting, the adoption of the method recommended, becomes still more imperative. In such districts as those just mentioned it may be advisable to cut out the trap corn and feed or burn it, if examination proves that the egg parasites and natural enemies are not especially abundant upon it. These points each planter must necessarily determine for himself and act accordingly.

EARLY AND LATE COTTON.

While upon a tour of one week in August, in the worst infested region of Texas, the late blooming and maturing cotton (whether the lateness was due to a peculiarity of the variety or to the late planting is immaterial) was almost invariably found to be the worst infested, and often the only infested, cotton in any given locality. In most cases this explains why one cotton field is greatly infested and an adjoining one not, or but slightly injured; the former usually being late, the latter early as to the time of most profuse blooming. Where early and late cottons occur side by side, the latter is at a great disadvantage, for it actually forms a trap crop, attracting to itself almost the entire egg deposition, which otherwise would have been distributed over the two fields.

It is therefore advisable to calculate upon having the cotton as far advanced as possible during July and August, for it must be evident that if the cotton be late and blooming profusely at the time when the destructive broods of those months appear, the attractions of the trap crop will be, to a certain extent, divided. From an entomological standpoint, it matters not whether this be accomplished by planting early varieties of cotton or by planting late varieties early enough to attain the same end.

BACTERIOLOGICAL EXPERIMENTS WITH INSECT DISEASES.

INTRODUCTORY.

The first portion of the work upon the availability of certain disease germs of insects as remedies against the Boll Worm was begun by another, whose report you already have. The writer assumed charge of this work at the close of the season, when it was impossible to accomplish anything further until the following year. Fresh material for further studies could not be obtained, and the cultures at hand, as a result of the outgoing season's labors, were entirely unsafe and unsatisfactory for scientific purposes. The following season the conditions were disappointing, in that the insect upon which the experiments were to be made was not plentiful and the weather conditions were such as to obstruct progress at every step. The laboratory was not complete enough for the most extended and exhaustive researches, and the time at command was considerably divided in attending to other portions of the investigation.

No noteworthy discoveries were made and no reliable ones could be rightfully expected in so short a time. So far as the strictly bacteriological work is concerned, it has just reached a satisfactory basis for exhaustive studies along the lines which the results of the investigation indicate as the most promising.

The studies were conducted as directed upon the practicability of artificially utilizing the germs of insect diseases as remedial agents. Accordingly the germs were isolated as pure cultures by the usual methods and artificial infection experiments made to ascertain the facts. The results as such are entirely satisfactory, though in no sense solving or setting at rest the problem under consideration. Yet, if properly interpreted, they contribute valuable suggestions relative to the basis upon which the problem should be considered, or a solution attempted. The results can not rightfully be taken in a negative sense except in respect to the method and the basis upon which they were obtained.

Practicability having been the object in these studies, only such experiments and observations are presented in this report as bear directly upon that phase of the problem. The minutiæ of some new methods of staining the germs, their specific descriptions, and like matters, are entirely omitted, since, for the purposes of this report, they might be confusing and misleading. If this discussion contributes in any way towards freeing the minds of some from misleading and unbacteriological opinions concerning the problem, or assists in putting future efforts on a more scientific basis, it will serve as great a purpose as our present knowledge of the specific organisms and the attending difficulties involved will permit.

GENERAL PRECAUTIONS.

It will be unnecessary to enter into a detailed description of the laboratory and apparatus used, for both were such as are always required for preliminary bacteriological studies. In general it can be stated that all the customary cleanliness and precautions were successfully observed. The apparatus was thoroughly cleansed after using, and either disinfected or sterilized. Glassware requiring it was placed in sulphuric acid for a time, subsequently washed, rinsed in alcohol, and sterilized. Test tubes in which cultures had been made were first filled with water, again plugged, and boiled for a couple of hours, killing the germs and lessening the danger of accidental infection from escaping spores. After boiling, the tubes were washed quite clean in water and placed in sulphuric acid over night. The following day they were washed, rinsed in alcohol, and sterilized. When making transfers of cultures from old to fresh media, the needles were always first dipped in acid and sterilized, then in distilled water, and again sterilized. To some these may seem to be extreme precautions, but the fact that the sterilizing, filtering, and culture inoculating was all done in the same small room, fully justifies them. That cleanliness and thorough disinfections were constantly practiced, may be concluded from the fact that at no time were any stock media lost through accidental infection or faulty sterilization. At no time was a culture lost through accidental contamination.

The incubator was provided with a thermostat, and the temperature controlled at will for any given purpose or set of conditions.

The infection experiments were carried on in another portion of the city. Two large rooms were fitted up, thoroughly cleaned and fumigated. In one the experiments with the particular microbe under study would be carried on, in the other the check experiments. Six-inch flower pots, covered with netting, were used as cages. These were thoroughly washed with a disinfectant before being employed in any experiment. For each experiment a different pot was used, to avoid the danger of mixing the germs. After each experiment, the room was thoroughly fumigated before another was begun.

CULTURE MEDIA.

Many media could be profitably experimented with in the study of reducing the problem of insect diseases to a practical basis. When, however, immediate practical results are wrongly considered the primary objects and experimentation is inaugurated upon that basis, it becomes impossible to use, at first, more than a few of the standard media. Those used in this work were beef broth, broth agar-agar, broth gelatine, and potato. The two most extensively used were beef broth and broth agar-agar, and for the purposes of this report it will

be sufficient to consider only these two. The following is a brief account of your agent's experience with, and methods of preparing, these two media:

BEEF BROTH.

The formula is the one most frequently used by Dr. S. A. Forbes and Prof. T. J. Burrill, of Champaign, Ill.: One pound of round steak, free of fat, is chopped fine, placed in 1 quart of water, soft preferably, and allowed to stand over night. The next morning the meat is pressed dry. It is well to pour some of the liquid back on the meat, stir up thoroughly, let stand for half an hour, and press again. Strain the liquid through cheese-cloth, measure, and add enough to make the original quantity (1 quart). Pour into a flask, boil in steam, sterilize for an hour and a half. Strain through cheese-cloth or white flannel, filter, and allow to cool. Measure, and if necessary add enough distilled water to make 1 quart. When about 60° C., neutralize with sodium carbonate (or if alkaline, with lactic acid). Cool to about 45° C., and allow to stand for half an hour. Filter. Boil for an hour, cool to 60°, and filter through double thickness of best German filter paper. Sterilize for an hour, and let stand over night. If sediment forms, filter while cold. It is now safe to fill test tubes and proceed with three discontinued sterilizations on as many successive days. In test tubes the sterilizations need not be continued for more than twenty minutes. In large quantities an hour or more is required.

The addition of the neutralizing agent often makes the liquid turbid. Added a little at a time and the liquid shaken, this cloudiness disappears. If so, it only indicates that the liquid is not yet neutral. As the point of neutrality is reached the cloudiness disappears less perfectly upon being shaken, and finally not at all, gradually forming a light, flocculent precipitate. The task of obtaining and retaining an absolute neutrality is a difficult one and the reaction just described, if carefully noted, will be of great assistance in making a delicate test.

Some recommend the use of the white of an egg to assist in clarifying the broth. The method already detailed was so satisfactory that egg was used in only a few instances and then more as an experiment. It was found, if the broth was neutral or alkaline when the white was added, that it coagulated imperfectly when boiled and caused considerable difficulty. The broth had to be acidulated and then boiled to produce the proper coagulation. The filtrate was clear at first, but the process of neutralizing produced the same effect as to cloudiness and fine sediment as already explained.

The white of old eggs is somewhat more liquefied than that of fresh ones, and when used in a quantity of slightly acid broth it was difficult upon boiling to produce perfect coagulation. This merely emphasized the fact that only fresh eggs should be used in the work.

AGAR-AGAR.

In the preparation of this, medium beef broth prepared as already described was used in every instance. For the most part, peptone did not seem to be required in the preliminary studies, and no time was spent in using it to determine additional differences in the growth ot the microbes studied. The agar-agar was finely cut before being placed in the broth to soak. It was found that the difficulty as to cloudiness in the media could be greatly lessened by soaking the agar-agar in water for a time and thoroughly washing before placing it in the broth. With these preliminary explanations, the following may be given as the formula, which is also the one used by Prof. Forbes and Prof. Burrill:

One quart beef broth.
Ten grams agar-agar.
Five grams sugar (yellow clarified).
Five grams salt (druggist's best).

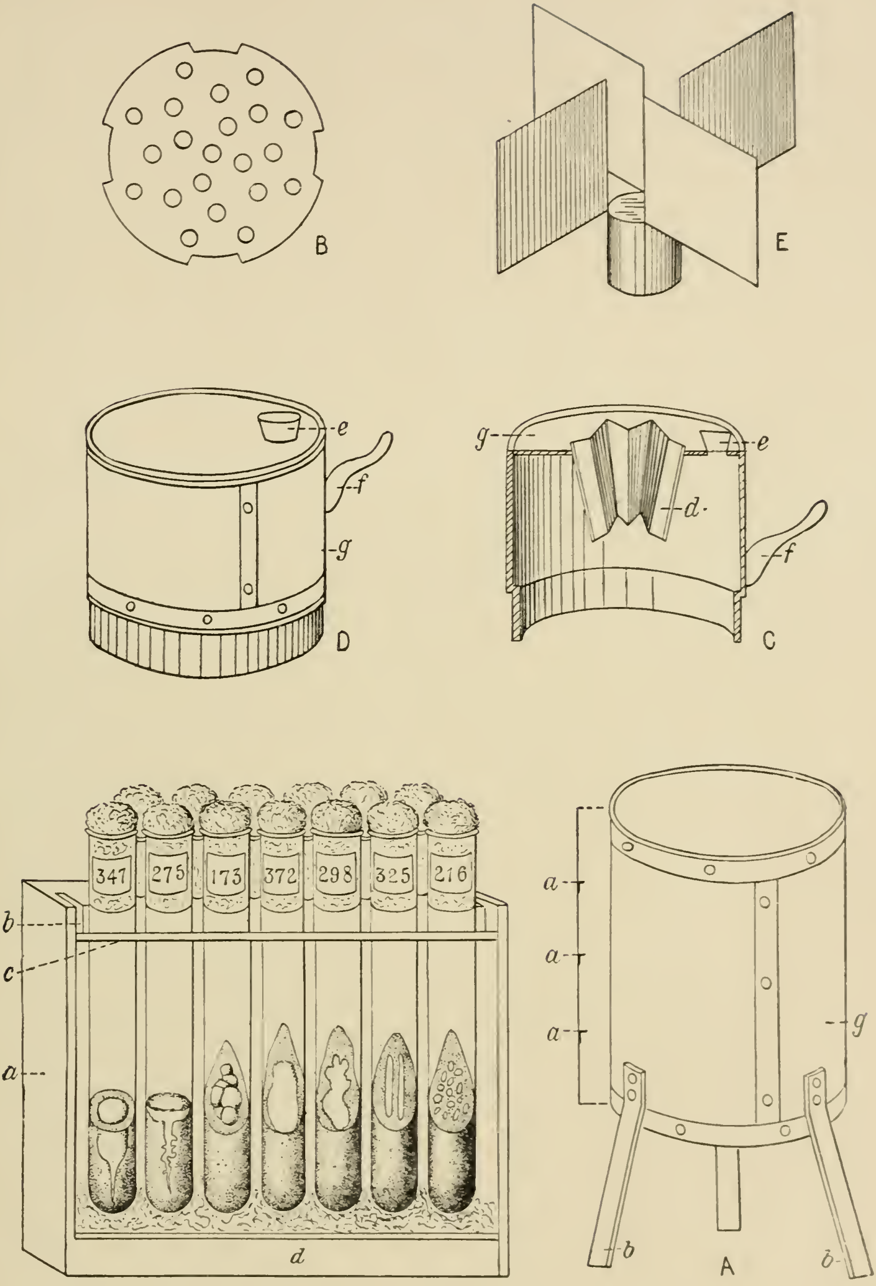
After shaking well, allow to stand and soak over night.

The following morning boil for three hours. Strain until clear; cool to about 60° C. Stir in the white of an egg and boil until well coagulated. Strain until clear; neutralize if necessary; keep hot without boiling, and allow to stand for fifteen minutes. Filter; sterilize for an hour. If sediment forms, filter again; sterilize for another hour, and let stand over night. If upon warming the next morning a sediment forms, filter again, after which it will be safe to fill the test tubes. These are then further sterilized the same as beef broth. After the last sterilization of the tubes the wire cage containing them should be laid on an inclined plane, so as to give a slanting and therefore greater surface in the tube for the growth of the germs.

The agar-agar medium sometimes looks slightly cloudy while yet hot or upon being heated, but, as in the broth, this disappears upon cooling.

SPECIAL APPARATUS.

The filtering of agar-agar and other solid media is often attended with great difficulties in winter, since the hot liquid cools and thickens so rapidly. For this reason an apparatus for hot filtering is necessary. A separate appliance requiring additional gas and burners is in common use. Your agent was compelled to secure the necessary apparatus speedily and economically, and accordingly the following combination of the steam sterilizer and hot filter was devised (see Plate II, Figs. A, B, C, D, E). The lower portion (A) of the sterilizer was made as usual; this particular one 10 inches in diameter and 1 foot high, with three circles of tips (*a*, *a*, *a*) on the inside, on which to lodge the perforated diaphragms (B) at various heights above the water. The legs (*b*) were high enough to allow an ordinary two-burner oil stove to



SPECIAL APPARATUS FOR BACTERIOLOGICAL WORK.

be placed under. The top or lid (*c*) was made 8 inches high, of the same diameter as the lower portion, fitting into it tightly, so as to avoid the escape of steam and decrease of pressure as much as possible. Through the center of this cover was fitted a collar (*d*) in the shape of an inverted cone, about 3 inches long, 4 inches in the larger and 2½ in the smaller diameters. For this collar a tight-fitting lid like that for a tin pail was provided, in order that the same top might be used either for hot filtering or simply for sterilizing. To one side of the funnel collar, in the top of the lid a second small collar was fitted, for the reception of a thermometer. On the side a slender, slightly bent handle for lifting the top off and on was placed.

When any hot filtering is to be done, the flask containing the medium is placed in the sterilizer and brought to a boil. At the same time a second empty flask is put in on the diaphragm. The top is then placed on. The funnel is provided with the necessary filter paper and the whole inserted through the collar (*d*) in the top of the sterilizer. The steam around the funnel keeps it hot and that escaping through the neck moistens the filter paper. When the liquid to be filtered reaches the boiling point, the flask containing it is taken out, the hot funnel at once fitted through the collar, into the empty flask, inside the sterilizer. The liquid is then poured into the funnel and the filtering proceeds without further interruption or special care. The body of the funnel being inside the sterilizer the steam has full play upon it, keeping it and the liquid almost at boiling during the entire process. At the same time other flasks containing media can be placed in and sterilized while the filtering goes on. The flask receiving the filtrate being in the sterilizer, any danger of falling germs or spores in the air settling upon the liquid is avoided.

The funnel collar should not extend more than a half inch above the level of the top, so as to allow almost the whole of the funnel to be inside the sterilizer.

For some media the pressure of the steam through the funnel checks the rapidity of the filtering. To avoid this a ruffled collar, instead of a perfectly circular one, can be made, thus allowing the escape of steam and relieving the internal pressure. The lid to the collar must be made to fit accordingly. If desirable a plain top (D) can be made for ordinary use in sterilizing, in which case the lid to the funnel collar in the other is not necessary. The respective dimensions must of course be adapted by each maker to his particular purpose. To prevent the radiation of heat as much as possible, the sterilizer is covered or bound in the usual manner with asbestos (*g*).

Another piece of apparatus, which may be called an "incubating cage," Fig. F, was also devised which in many respects materially facilitates work. The cages in which culture tubes are usually placed when transferred to the incubator are the well-known wire cages, holding some twenty or thirty tubes. This entails a great inconvenience

when many cultures are in consideration, since neither the labels on the tubes nor the nature of the growth can be readily seen without taking out each individual tube. This difficulty is overcome in the new cage, the frame of which consists of wooden strips three-eighths or one-half inch thick, and about 1½ inches wide. The two upright ends (*a*, *a*) should be about 4 inches high, with grooves (*b*, *b*) cut along each side into which a plate of glass, *c*, can be slipped. The two uprights are dovetailed into the horizontal piece (*d*), pegged and firmly glued. This done, the two plates of glass are inserted, the bottom covered with cotton to the depth of half an inch, and the tubes placed in as shown in the figure. In doing so the slanting surface of solid media should be turned to the outside and the label placed on the same side. In this way no difficulty is experienced in speedily finding any tube desired and watching from the outside what progress any growth may be making. The cage should be wide enough to receive two rows of tubes, as then there is less danger of its falling over so easily. They can be made any desired length, and the uprights to any height demanded for the best tubes in use.

OBSERVATIONS AND EXPERIMENTS.

June 11 a Boll Worm was placed in a cage to rear in confinement. It fed until June 13, when it entered the earth for pupation, but died in the attempt, June 15. The anterior part of the body began to decay and then darken. At the decaying portion a cut was made dorsally with the proper precautions, and a brownish golden-colored liquid issued. A drop of this was transferred to a tube of broth and a liquid culture made. From this in the usual manner pure cultures were obtained on solid media. The posterior portion of the body did not decompose so rapidly, and though rather spongy, retained its natural color for some time. As the rotting proceeded, the color changed to a brownish or darker color.

The germ which probably caused death changes beef broth to a decided white turbidity, with scant white deposit at first. As the growth advances the deposit becomes more abundant and the liquid begins turning greenish. Finally, the broth clears and is a beautiful deep green, with plenty of white sediment at the bottom. On agar-agar the growth is very thin and scant, beginning by numerous small, irregularly roundish, almost colorless colonies. They gradually spread a little, and if numerous enough form a thin, rather granular-appearing white film. The first pure cultures on solid agar media give the medium a faint, greenish tinge, but this power seems gradually to weaken with subsequent cultures. The germ was found to be quite sensitive to artificial cultivation, and doubtless loses much of its original power by such a process. In some respects the growths upon agar-agar and beef broth are quite similar to those of the cabbage-worm

(*Pieris rapæ*) disease, but a microscopic examination shows the former to be a rather small bacillus.

A similar observation was made June 19, when one of a lot of Boll Worms kept in a breeding cage for life-history purposes was found dead. A bacteriological study was made. The alimentary canal seemed to be the only portion of the body containing much liquefied matter, the fatty portions being rather slow to decay. Pressure of the decaying anterior third of the body forced out a drop of a rather golden-colored liquid, from which a broth culture was made. At the same time a pro-leg was snipped off with sterilized scissors, a platinum needle inserted so as to miss the alimentary canal, and a second tube of broth inoculated. From each pure cultures upon agar-agar were isolated. In the beef broth the changes were the same as just described in the preceding study. Upon agar-agar a more profuse and vigorous growth was obtained, which was partly due to the fact that the tubes had been more recently prepared and were not so dry as in the first study. The film was smooth and white, with margins entire though irregular in some portions.

This affection of Boll Worms is not very prevalent, though occasionally one is found in ears of corn dead or dying. From these in most cases the germ just considered can be isolated by the usual pure culture methods. When affected, the larvæ seem to lose their appetites, cease feeding, become rather sluggish, and appear somewhat disturbed. The color of the skin remains either partly or entirely normal, occasionally even for a time after death. At the same time, however, the tissues of the body are decaying and becoming watery, more especially along the alimentary tract. This condition at last imparts a grayish-brown or rose-tinted color to the body.

Both cultures of this boll-worm bacillus were made from the pure ones on agar, and allowed to grow for eighteen days, when they were used in experiments 1, 2, and 3, which follow.

Experiment 1.

July 8 (*5:30 p. m*).—The husks of an ear of corn were torn aside and the silks and grains for a considerable space were well washed with the broth culture of the bacillus. One nearly grown Boll Worm and one half grown, were placed within the husks, after which these were well closed down upon the ear. The ear was kept in a pot prepared as heretofore explained.

The following day both larvæ had fed freely upon grains of corn which had been drenched with the broth culture. No unfavorable symptoms. The second day the large worm had left the ear and entered the earth for pupation. The small one was still feeding but showed no unhealthy symptoms. The third day the young larva molted. After this it continued to feed in the ear, pupating there and completing its transformations by issuing as a moth July 27. The first pupa had hatched a few days earlier.

Experiment 2.

During the same period of time four cabbage worms (*Pieris rapæ*) were fed upon a cabbage leaf which had previously been well drenched with a portion of the broth

culture used in experiment 1. One of the larvæ was almost grown, one about half grown, and the others younger.

The following day, July 9, the drenched leaf had been almost entirely eaten up. They were left to feed upon the remains until the second day, when a fresh leaf was placed in.

Up to July 14 no symptoms of disease appeared in any of the larvæ, and on that day the last two pupated. July 15 the two oldest pupæ died. One of these had beed noted as turning darker the previous day as if beginning to rot. To-day its wing-covers and head are entirely black, while the abdomen practically retains the normal color. The other dead pupa is entirely of a uniform dusky color. The two living pupæ were lying just alongside the two dead ones, and were thoroughly exposed to infection, if any. Both, however, hatched, one on July 18, the other July 22.

Experiment 3.

July 8.—The culture liquid used was the same as in experiments 1 and 2. A small cabbage leaf was drenched and four *Pieris rapæ* larvæ placed to feed. Two of them were nearly grown, the others about half grown. By July 10 the leaf had been entirely eaten, but no symptoms of disease were noted. Fresh leaves were placed in July 13. July 15 two pupæ were found, one being imperfectly formed. The two remaining larvæ fed freely, but did not seem to grow as rapidly as usual. At times their skin seems to be somewhat puckered and appears rather dusky. July 16 the ill-formed pupa is dead. July 18 the last larvæ pupated. July 27, without any apparent outward changes to forewarn such a result, it was found that all the pupæ had died. About the time of death, or soon after, the color becomes slightly brownish or dusky. The special attention due this experiment was frequently interrupted and fresh food was not provided the larvæ as often, perhaps, as was conducive to their best development. This may have induced them to attempt pupation rather prematurely, or have weakened them so as not to be able to cope with the germ.

Checks on experiments 2 and 3.

The larvæ in experiment 1 having completed their transformations without difficulty, a consideration of its check will not be necessary. For experiments 2 and 3 a number of *Pieris rapæ* larvæ were placed upon cabbage leaves in a separate jar to act as a check.

July 9 the following was the condition of the larvæ in the check: 1 pupated, 3 pupating, 4 grown, 1 half grown, and 3 younger. Up to July 16 the younger larvæ had kept on feeding perfectly, and succeeded in maturing and pupating. Two adults issued on this day, and one pupa, which had been injured a few days before, was dead. July 17, 8 pupæ remained. Two had become darker in color, as if beginning to decay internally. Later these 2 were found to be certainly dead, the one having turned quite blackish, the other more brownish gray. The other 6 hatched.

One of the dead pupæ of experiment 3 was taken for further study. The contents were a blackish liquid mass, from which a drop was taken with which to inoculate a tube of broth. From this other liquid cultures were made, and from these pure cultures upon agar-agar were obtained by the ordinary process. One of the dead pupæ was taken from the check for a similar study. Its contents were of the same nature as of the one just noted. In the same manner liquid cultures, and from these pure cultures upon agar-agar were obtained. A careful comparative study proved that the pure cultures obtained from the two pupæ were identical, and a microscopic study developed the fact that both were cultures of the Micrococcus of the cabbage-worm disease. Accordingly the pupæ in experiments 2 and 3 did not come to their deaths solely through the agency of the boll-worm disease, though the greater per cent of deaths in the experiments, as compared with that of the check, would indicate that the latter germ contributed in some manner to this end

Some diseased cabbage worms were received October 4 from Prof. C. P. Gillette. Ames, Iowa. From one of these larvæ a pure culture of the *Pieris rapæ* micrococcus was obtained. In this condition it was kept in a healthy growing state during the winter by frequent transfers to fresh media. In this manner the germ had been transferred eleven times, nine times on agar-agar and the last two in beef broth. The eleventh culture was used in the experiments August 20, after having had about ten months of artificial cultivation. The culture was two days old when used in experiment **4.**

Experiment 4.

August 20.—The culture liquid just spoken of was applied as follows: Two small bolls with involucres were well drenched in the liquid and two half-grown Heliothis larvæ were placed on them. The larvæ began sipping of the liquid, which insured their infection if possible. A small round cavity had been cut into the bolls and filled with the culture liquid. The worms decided to enter the bolls at these injured points, again exposing themselves to infection. Both continued healthy and fed freely, so much so that one fell a victim to the other through cannibalism. The survivor continued healthy to the last, pupated, and hatched later as a robust, active moth.

In isolating the cabbage-worm micrococcus from the diseased larvæ received from Profs. Osborn and Gillette, two other germs were isolated. On agar media the one produces a yellow growth, the other a beautiful pink one. In all the previous and subsequent studies the germ producing the pink growth was almost constantly obtained from diseased cabbage worms. It was therefore thought advisable to give it a trial upon the Boll Worm. A broth culture was made and allowed to grow for two days, when it was applied as detailed in experiment 5. The germ had been carried over winter by artificial cultivations for a period of eight months and was the tenth pure culture.

On agar-agar the growth may be described as follows: At first small elevated round colonies having a translucent whitish appearance. These gradually spread and fuse, forming a continuous white growth. If it continues growing from the margins, these may be finely fringed, slightly branching or corrugated. As the growth becomes thick, the surface becomes very much wrinkled or ridged. At this stage, and often earlier, the growth begins turning to a pinkish color, finally becoming distinctly pink. The pink color appears in smooth growths or isolated colonies, as well, seemingly, developing as the germ ceases its most vigorous growth. The wrinkled scum seems rather to be evidence of a vigorous culture and the result of a very profuse growth.

Experiment 5.

August 15.—The husks of an ear of corn were torn away just enough to expose the silks and grains of corn. The culture liquid was then poured on the tip of the ear and allowed to soak in through the silks and run down the length of the ear. One large Boll Worm and one half grown were in the ear. The liquid came into contact with both, and each was seen to sip of it. The following day the larvæ had eaten plentifully of the corn, including most of the grains which had been drenched with the charged liquid. Both larvæ continued to feed, the larger one pupating and hatching later. The smaller one fed for a time longer, during which no unfavorable symptoms appeared, but finally made good its escape from the pot while searching for a more desirable place to pupate.

The disease of *Pieris rapæ* is found occasionally in most portions of Louisiana, but it is not of a virulent form in most cases, not causing death until the pupal stage is reached. June 8 two dead pupæ of this species were found upon cabbage plants in the field. A careful study

proved that they were not parasitized, and had not been injured. Pure cultures on solid media were isolated from the germs found in the liquid contents of the pupal skins. One of these germs proved to be the cabbage-worm micrococcus. In most portions of the South the disease affects only a small percentage of the larvæ, and as it is usually fully developed only in the pupal form, the contagion among cabbage-worms is reduced to a minimum.

A DISEASE OF PLUSIA BRASSICÆ.

The first symptoms begin to appear about the region of the two white lateral patches just below the median line and over the first pair of prolegs. The patches look like whitish, cheese-like fatty bodies under the skin. From these the pale cream color of the body begins and spreads, the skin gradually becoming entirely of a lemon-yellow color. The posterior portion of the body shows these symptoms first, the anterior portion remaining quite natural in color until about the time of death. No fluids appear to issue from the mouth or vent during the course of the disease. When well affected by the progress of the disease, the larva ceases feeding, dying soon afterward. The entire body deliquesces very rapidly after death, producing a blackish, semifluid mass suspended in a bag of grayish skin, which finally bursts and allows its contents to escape.

September 4, some living Plusia larvæ were found on a cabbage leaf near a dead Plusia larva, which was already black and entirely deliquesced.

Two Plusia larvæ and two of Pieris from the same plant were placed together in a collecting box, and later placed in the same breeding cage to rear. By September 7 the Plusia larvæ had died and deliquesced. The Pieris larvæ had certainly come in contact with the sick Plusia while crawling about and feeding upon the same cabbage leaves, and had thus been thoroughly exposed to infection. Both larvæ, however, completed their transformations, and the butterflies showed no unfavorable symptoms. This experiment was repeated with a greater number of larvæ of each species with exactly the same results.

From this it becomes evident that the Plusia disease could not be very contagious so far as *Pieris rapæ* was concerned; at the same time the disease acts very decidedly and rapidly among Plusia larvæ. They often begin turning pale cream-colored, then yellowish, dying, and the body deliquescing, all within thirty to forty hours. This applies to nearly grown larvæ. Those less than half grown succumb in half that time.

In the usual manner pure cultures were obtained from the dead and deliquescing larvæ. Three distinct germs, two of which were found almost constantly in the several specimens from which cultures were made, were isolated by the usual process. On agar-agar one of these germs produces, at the beginning, numerous small, white roundish

colonies, which gradually spread and form a thin, white granular film, margins wavy or sometimes slightly corrugated. The growth has a slight tendency to liquefy at a certain period of its development. The second produces a pink growth, such as has been noted and described in considering experiment 5. The third is a profuse beautiful yellow growth, beginning at first by dense, thick round colonies, rather whitish at first, but soon turning yellow. When fused and the growth pretty nearly completed it is nearly always quite thick and deep yellow, with margins entire or wavy. The first and third of these are the ones which seem to be constantly associated with the disease. The one producing the thin, white film is the one which is parasitic, or at least partially so, in its relations to *Plusia brassicæ*.

Pure cultures of this germ were also received June 3 from Dr. J. C. Neal, Lake City, Fla. Upon unsealing the tubes a small amount of gas escaped with a fizz, accompanied by a smell reminding one of rotten eggs. Fresh agar cultures were made, and from these, liquid cultures were prepared for use in experiments 6 and 7. The culture liquid used in these experiments was eighteen days old.

Experiment 6.

June 27.—A cabbage leaf was drenched with the charged liquid, and four Pieris larvæ placed on to feed. The day following all were feeding briskly. Two days later the leaf had all been eaten and fresh food was placed in. No indications of disease three days afterward. Later three larvæ pupated, one of which was accidentally injured and died. The fourth larva died, but did not rot or turn dark. It dried up gradually, which indicated that the pot had been too strongly disinfected and that the larva had been poisoned from crawling about its walls. No cultures were subsequently obtained from it. The two living pupæ hatched in due time.

Experiment 7.

June 27.—Two bolls were prepared as described in experiment 4, but using the same culture liquid designated for experiment 6, namely, the Plusia disease germ. Two Boll Worms were placed on, and each was subsequently observed sipping of the liquid. One of the larvæ was full grown, and had shortened some, preparatory to pupation; the other was also about full grown, but fed until mature. Both subsequently entered the earth and completed their transformation without any difficulty.

Checks during the progress of the experiments recorded, and many others were carefully continued. Since no results were obtained from the experiments requiring it, the consideration of the checking will, in this report, be superfluous, save to remark that disease did not appear in them in any instance, except experiments 2 and 3, which have already been included.

DISCUSSION OF THE RESULTS.

From the beginning complicating conditions were discovered. The most important one was that the species in question (*Heliothis armiger*) was subject to a disease which was probably as prevalent as the nature

of the case permitted. Great results had been anticipated by some from an introduction of the disease of the Cabbage Worm (*Pieris rapæ*) as a remedy for destroying the Cotton Catterpillars (*Aletia xylina*) or the Boll Worm. Upon investigation it was found that this disease had already been introduced with its host through the natural dissemination of the disease from the locality of its first appearance. The third complication arose when it was observed that about 80 per cent of the larvæ of *Plusia brassicæ*, a very common cabbage insect in the South, were dying of disease. The importance and relation of these three conditions to each other will be better appreciated by bacteriologists when it is explained that the system of small negro tenantry, which is customary in the greater portion of the cotton district, results in numerous small garden patches along the edges of, and often within, the centers of the fields. The one vegetable which can safely be predicted to be present in nearly all of them is cabbage. These plants were always infested with either *Pieris rapæ* or *Plusia brassicæ*, or both, and concerning both it was known that disease made its appearance. The Boll Worm and Cotton Catterpillar were therefore constantly exposed to the danger of infection. As a consequence, in the studies for the artificial infection of the Boll Worm, the following sources of error required elimination: First, infection through its own peculiar germ; second, through that of *Pieris rapæ*, and, third, through that of *Plusia brassicæ*. This could be best guarded against by determining, as much as possible, the relation of the three germs to the three insects involved. Before these points are discussed, it is advisable to dwell upon some other conditions of environment which will contribute to a better interpretation later.

It is asked, why does not the disease of the Boll Worm itself spread more freely? The diseased Boll Worms, with few exceptions, were found in ears of corn. Here, as has been stated in the first part of this report, a struggle for food, due to crowded conditions, may and often does occur. This compels more or less traveling in search of suitable quarters. This in turn increases exposure to all sorts of unfavorable conditions, including the attack by parasites and natural enemies, as well as disease. Further, having probably fought for its freedom, the larva is forced to change at a time when it is weak and least fit to resist such conditions. It is under these conditions that the Boll Worm sometimes falls a victim to disease, usually, however, getting under the cover of another ear before dying, thereby lessening the chances for its infecting others of its own species. In view of these facts, the trap-corn method recommended in another portion of this report becomes an important factor, in that for this species it furnishes those conditions which are favorable for the greatest propagation of disease.

When the Boll Worm infests cotton, the chances for infection are even more diminished, in that each individual becomes a hermit in addition to feeding on the inside of the cotton boll. Upon cotton they seldom

come in contact with each other, and then for a brief time only. Therefore, should a Boll Worm become diseased upon either corn or cotton, the natural conditions and habits of the past are such that the chances for infecting other individuals through it are reduced to a minimum. This also explains the failure of the disease of *Pieris rapæ* and *Plusia brassicæ* to attack the Boll Worm, and spreading to it through the natural processes of infection and dissemination. On this point, however, another consideration must be noted in the case of *Pieris rapæ*. From the observations already recorded for this disease, it is found that, though present, it developed rather tardily in its host under the prevailing conditions. In addition, it appears to be less virulent and apparently has less power of contagion, since it does not seem to infest others of its own species so readily as in more northern districts, such as Illinois, Indiana, and Iowa. This seems to be due mostly to the differences in climatic conditions, the atmosphere being drier, much higher in temperature, and the hot summer season much more protracted in the South. The well-known devitalizing effect of hot, scorching sun-light under high temperatures upon many bacteriological organisms seems therefore to explain the lesser virulence of this germ in the locality where the investigation was prosecuted. Accordingly, the Pieris disease is unpromising at present as an agent in destroying the Boll Worm in that section. The germ is doubtless becoming more acclimated and adapting itself to prevailing conditions, so that it may be expected to become more efficient in that region in the future.

For the Plusia disease, however, the high temperature seems to be a necessary factor, and, so far as the writer's information goes, is less virulent in the cooler or northern districts.

Experiment 1, in which a pure culture of the boll-worm germ obtained by artificial culture methods was fed to healthy Boll Worms, failed again to produce the disease. The same germ was fed to larvæ of *Pieris rapæ* as detailed in experiments 2 and 3. In experiment 2, 50 per cent died. In experiment 3, all died. Subsequent studies of the dead pupæ in these two experiments, as also the records of the checks upon them, together with microscopic examinations, proved that death could not be attributed to the boll-worm germ with any degree of certainty. On the contrary, death seems to have been due to their own specific germs, as noted in the experiment. Reversing the trial, the germ of Pieris was used in experiment 4, and fed to the Boll Worms without producing disease. The Plusia germ was then fed to Pieris larvæ as in experiment 6, and to Boll Worms as in experiment 7, without bringing about diseased conditions. Furthermore, Pieris larvæ, feeding upon the same plants and leaves along with diseased Plusias, did so with perfect immunity.

What does it all mean? It is unsafe to hazard any positive statements and the discussion must be understood as being provisional. Granting that the germs in question are truly parasitic upon their re-

spective hosts, the first important fact indicated is that they are emphatically specific as to the conditions required for their development. If this be so, the great differences in the life constitution and food of the three species of larvæ under consideration would at once render mutual intercommunication of their respective diseases impossible. The theory held by some that a parasitic germ is readily transmissible from one species to another with power to produce disease, must be dismissed. Experience has shown that producing disease by artificial means in one species furnishes no guarantee that the same germ can in like manner be used to produce disease in a nearly-related species and certainly not for those of distant relations. Actual experiment may prove it to be possible, which should therefore be done before any assertions are justifiable.

The behavior of the germs in question, under the artificial culture conditions recorded in the experiments, indicates that they are facultative rather than true parasites. This means that the germs can and do under certain conditions, develop as parasitic organisms, but under unfavorable conditions can undergo their development in other than living matter and thus tend toward saprophytism. Accordingly they may gradually adapt themselves to being more saprophytic or more parasitic, whichever the prevailing environment may favor. This is quite certainly the nature of these organisms in relation to species of insects other than the one which for convenience may be called the natural host. Therefore the apparently negative results shown in the experiments are negative only as concerns the utility of the germ when used in the facultative condition in accordance with the usual method of procedure. The germs being facultative in their nature, cultivations on artificial culture-media begin at once to weaken their power to produce disease. When a facultative organism, therefore, is used in the usual manner to produce artificial infection, failure is rather to be expected, and it is manifestly erroneous to consider the results as having any direct bearing upon the practicability of parasitic organisms as remedial agents. The only interpretation which should be given the results recorded in the preceding experiments is that to the insect in question (*Heliothis armiger*) the germs cultivated and experimented with, bear only a facultative relation. This fact suggests the abandonment, as a primary method, of the generally accepted one for experimenting with germs in the attainment of practical economic results. This consists in the simple isolation of an organism as a pure culture, feeding it to a given insect, and passing final judgment according to the results which follow. It further suggests that before the question of artificial infection can be satisfactorily solved, the germ used, whether really parasitic or only a facultative parasite, must first be studied in all its relations to environments which allow the organism to produce disease. This done, the next step will be to determine how best to control those conditions by artificial means, either in relation to the host

itself or for fixing upon the microbe a greater power for infection or a coöperation of both upon the same basis. Either cause would result in attaining the greatest infection.

In preparing pure cultures the records show that in the process of isolating the desired germs from the dying host, at least one and sometimes two additional well-defined germs were obtained, which were either associated or coincident with the disease. It is an interesting and important study to determine what are the relations of these germs to each other, either preceding or during the progress of the disease.

Primarily the results of the observations and experiments develop the following facts:

(1) That the germs experimented with are only facultative in their relation to the Boll Worm.

(2) That, as such, in the manner cultivated and in the condition applied, they fail to produce results which are of primary economic importance.

(3) That such failure has no primary bearing upon the availability of strictly parasitic organisms to assist in producing infection by artificial methods and obtaining practical economic results.

Secondarily they rather definitely suggest the following general propositions:

(1) The importance of giving the most exhaustive study to ascertain what environments, as to both the insect and the germ, are favorable or unfavorable to the infection and development of disease among insects.

(2) The importance of first determining the biological character of the organism, *i. e.*, whether truly parasitic or only facultatively so.

(3) The determination of the first and second specifies to a great extent the further method of procedure, and the basis of experimentation.

(4) The importance of the three preceding considerations demonstrates the folly of attempting to obtain practical results by pure cultivations and artificial disseminations, purely as such.

(5) That making the attainment of practical results the primary basis of such investigations is a mistake, and an obstacle to real progress in their final attainment. This suggests that—

(6) The biological and physiological properties of the germs, together with their environments, should first be studied and determined upon a purely scientific basis, without regard primarily to the attainment of practical results.